PEANUT RESPONSE TO CALCIUM, SEED TREATMENT, MICRONUTRIENTS, AND PRIOR CROPPING HISTORY ON THREE SOIL TYPES

BY

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Florida recommended 600 kg calcium (Ca)/ha as a minimum soil extractable Ca level for peanut production in 1976. This was in contrast with Alabama which recommended 275 kg Ca/ha. Florida recommended 0.56 kg boron (B)/ha and had no recommendation for molybdenum (Mo) for peanut production.

Laboratory, greenhouse, and field experiments were conducted to determined the effect of Ca, B, and Mo on yield and quality of peanuts. Limestone pelleting of seed was evaluated as a method of supplying inoculant plus B or Mo to the seedling.

Calcium additions produced no significant yield or quality increase on either Florunner or Early Bunch peanuts. However, all soils for which yield and quality were evaluated were above 600 kg extractable Ca/ha. Addition of Ca did increase leaf Ca concentration, but did not

significantly alter kernel concentration of Ca. Addition of Ca to Lakeland sand in the greenhouse significantly increased fruit Ca from 388 to 437 ppm, but the increase came only from Ca applied to the fruiting medium, not Ca applied to the root system.

Limestone pelleting had no effect on emergence or nitrogen (N) concentration of seedlings for either Florunner peanuts grown in Arredondo fs or Early Bunch peanuts grown in either Arredondo fs or Orangeburg sl. Addition of 92 mg B/kg Florunner seed in the pellet induced B toxicity of the seedling, reduced emergence 18%, and decreased pod yield 37%. Addition of 23 mg B/kg seed had no effect on emergence or yield, but did not influence leaf B concentration for more than seven weeks. Addition of 34 or 68 mg Mo/kg Early Bunch seed slightly increased emergence and N concentration of seedlings on both Arredondo fs and Orangeburg sl, but had no significant effect on pod yield or seed quality in the Arredondo fs.

Addition of 1 kg B/ha in five foliar sprays or 1 or 2 kg B/ha applied in the soil maintained leaf B significantly above tha 0 B plants throughout the growing season. Addition of 1 kg B/ha in one spray at first bloom failied to maintain increased leaf B for more than eight weeks. Addition of B to either foliage or soil failed to significantly increase kernel concentration or to affect pod yield or seed quality.

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INTRODUCTION

Peanuts are the thirteenth most widely grown crop in the world. Peanuts are peculiar in that soil calcium (Ca) is necessary not only for root uptake, but for uptake by the developing fruit as well (Bledsoe et al., 1949; Skelton and Shear, 1971). The various states have different criteria for supplemental Ca applications for peanuts. Alabama currently does not recommend supplemental Ca if the soil pH is above 5.8 and Mehlich 1 extractable Ca is greater than 250 pp2m (Hartzog and Adams, 1973). At the initiation of this study, Florida recommended Ca additions if soil tests values were below 600 lb Ca/a (600 pp2m for runner varieties (Florida Cooperative Extension Service, 1975)).

Peanuts deficient in boron (B) display a lack of seed endosperm formation called hollow heart because the two halves of the seed do not meet. Both Florida and Virginia currently recommend 0.56 kg B/ha as a foliar spray on peanuts (Hallock and Allison, 1980; Florida Cooperative Extension Service, 1975). Boron is implicated in the permeability of membranes to potassium (K) (Pollard, et al., 1977; Smyth and Duggar, 1980) and Ca (Caroni et al., 1977) and therefore may have an influence on gynophore Ca uptake.

Limestone pelleting of legume seed is an accepted method for inoculating pasture legumes, but has found limited application to row crops. It was felt that manipulation of the seed would split the seed coat (Reddy and Tanner, 1980).

Effects of molybdenum additions to peanuts have not been widely studied (Anderson, Boswell, and Welch, 1963). Molybdenum is not a recommended fertilizer by any state, but little work has been done with Mo for the now standard peanut varieties.

The objectives of this study were:

1. To determine the effect of boron additions on Ca uptake by peanuts.
2. To determine the effects of pelleting peanut seed with limestone and inoculant.
3. To evaluate the effects of the following micronutrients applied in the seed pellet, to leaves, or to soil.
   a. Boron (B)
   b. Molybdenum (Mo)
   c. Tungsten (W)
4. To investigate differences between Alabama and Florida recommendations for Ca supplements to peanuts.
5. To determine effects of prior cropping history on peanut growth and yield.

LITERATURE REVIEW

Boron

General

Boron is the only non-metal in Group 111A in the Periodic Table. Boron (B) was first isolated simultaneously by the English chemist Davy and the French team of Guy-Lussac and Thenard in 1808 (Newkirk, 1961). Boron has an atomic radius of 0.86 angstrom and natural distribution is 80% ^{10}B and 19% ^{11}B (Bower, 1970). Boron derives its name from the Persian and Arabic "borak" which means white. Borak was the name for deposits of borax found in the desert (Massey and Kane, 1972). Boron is found in the earth's crust at an average 3 ppm (Massey and Kane, 1972) but total soil content varies widely according the parent material. Igneous derived soils contained 14 ppm and sedimentary rocks contained 40 ppm B in a survey by Bingham (1971). Soils derived from marine shales contained up to 68 ppm B.

Boron in soil

Elder and McCall (1936) discovered tourmaline crystals in the sand fraction of B sufficient soils. Study of soils which had a history of rutabaga (*Brassica naprobrassica* L.) showing brownheart revealed no tourmaline crystals. The researchers concluded that tourmaline was the source of B for plants.

Boron is present as boric acid (H_3BO_3) in the natural pH range of soils (McPhail et al., 1972). Oliver and Barber (1966) observed that mass flow was probably the major mechanism for movement of B to the plant root.

Eaton and Wilcox (1939) conducted many studies with B in different soils. They concluded that plant available B was supplied by the decomposition of soil organic matter, but that B was fixed by magnetite and bentonite when added as borax. They hypothesized that B formed silicates since the amount of B fixed was increased by either grinding the soil prior to B addition or drying the soil after. The newly added B was not easily removed and the authors proposed the increased retention was due to increased cation exchange capacity.

Frederickson and Reynolds (1960) developed a diagram for determining the origin of salinity in paleozoic water. Their premise was that illite absorbs B and does not release it while the other clay minerals will release B not found in the crystal lattice. Since all shales tend to be high in B, the minerals Frederickson and Reynolds examined were pretreated to remove adsorbed B and the total B of the minerals was compared to standards.

Couch and Grim (1968) attempted to explain this special relationship between B and illite. Their studies showed the initial reaction to be an edge chemisorption following Freudlich's hypothesis with a secondary intercrystalline diffusion of the $B(OH)_4^{-1}$ anion.

Rhoades, Ingvalson, and Hatcher (1970) studied desorption of B from soils naturally high in the element. They discovered the Langmuir

desorption coefficients did not adequately describe the behavior of B leaching from the natural soils, but Langmuir did describe the removal if the soil had all native B removed and then replaced. The predicted values were always low due to a regeneration factor which renewed soluble B if the soil was allowed to re-equilibrate after leaching. The authors stated that the origin "of the additional B released after re-equilibration" has not been identified, but the weathering of boron containing minerals, decomposing organic matter, or dissolving boron salts are possible sources."

The breakthrough discoveries for the behavior of B in soils were published almost simultaneously by two groups: Hatcher, Bower and Clark (1967), and Sims and Bingham (1967). Both groups discovered that the amount of B retained by a soil was determined by the amount of hydroxy-aluminum found in that soil. Hatcher et al. (1967) worked with 21 soils and obtained a straight line relationship between the amount of B absorbed by a particular soil and its specific area multiplied by the square root of the citrate extractable Al^{+3}. Hatcher's group also lent insight to the puzzling pH phenomenon of why available B declines when soil is limed. They obtained a straight line relationship between the amount of B a soil will absorb and the decrease in exchangeable Al caused by liming. The liming causes the free Al^{+3} to precipitate as $Al(OH_3)$ which is very reactive with H_3BO_3. McPhail, Page, and Bingham (1972) showed maximum adsorption of boric acid by hydrous aluminum occured at pH 7.5. McPhail et al. (1972) showed a profound effect of surface area of the alumina and amount of crystallinity on the absorption of B, with freshly precipitated $Al(OH)_3$ having the greatest retentive power for B.

Independently, Sims and Bingham (1967, 1968ab, 1968b) were conducting experiments with purified clay minerals. Their study compared B retention by two vermiculites, a montmorillonite, and a kaolinite. The montomorillonite and one of the vermiculites were pretreated to remove surface impurities. The other vermiculite and the kaolinite were not treated. The untreated minerals were both high in B adsorption while treated minerals were much less reactive. To investigate the discrepancy between the two vermiculites, the previously untreated vermiculite was washed with NaCl, then the sample was split and one half was treated with KCl to collapse the interlayer. The vermiculite then behaved as the other treated vermiculite. Analysis of the NaCl wash water revealed 760 ug Fe/g and 106 ug Al/g. The loss of B adsorption led Sims and Bingham to investigate the reactions between pure iron and aluminum hydroxides and B.

Sims and Bingham (1968a) prepared fresh Fe and Al hydroxides by reacting their chlorides with 2 M NaOH. They found the hydroxides lost ability to absorb B within a short period of time. The Fe material retained only 75% of the B that fresh Fe hydroxide did if it was allowed to age one day before the addition of B. After three days the retention rate was only 25%. This trend remained for the precipitates of Fe-B when the fresh hydroxide was allowed to react with $B(OH)_3$. Boron was released as the resultant precipitant aged and the release of B was linear to 28 days. No B was released after 28 days.

Aluminum borates adsorbed much more B and released it in a different manner than Fe borates. The systems were similar above pH 9, but at pH 6 very little B was released from the Al systems. The hypothesis was

that at higher pH the B is expelled as the Al and Fe material undergoes hydrolysis, but the Al-B compounds at pH 6 resist hydrolysis.

Sims and Bingham (1968a) proposed anion exchange as the mechanism for B retention. The exchange could occur by replacement of an hydroxyl ion by a borate ion. This reaction was suggested by McPhail et al. (1972), who explained the decline in B retention by Al and Fe hydrous oxides at pH greater than 8 by pointing out the possible competition of OH^- and $B(OH)_4^-$ for adsorption sites. The reaction could possibly be a borate diol involving the loss of two water molecules as the borate anion is bound to the two Fe or Al atoms through oxygen bridges. Since the retention of B occurs at higher levels with increasing pH, and the diol reaction is favored by higher pH, Sims and Bingham (1968a) concur that the diol reaction may be more prevalent, but admit the mechanism would be difficult to discern.

Sims and Bingham's Fe-B and Al-B precipitates were analyzed by the mole ratio method. Compounds such as $Fe_3(B(OH)_4(OH, O)_x$ and $Al(B(OH)_4)(OH,O)_x$ were proposed. The mole ratios for the Fe-B compounds were well correlated with pH when pH 6 systems had a range from 1.33 to 3 while pH 8 systems ranged from 0.5 to 0.75. The pH-ratio was not as well behaved for the Al-B systems. The mole ratio was between 1 and 3 regardless of pH.

Sims and Bingham then added Al to their purified clay minerals. In all cases the addition of amorphous Al increased B retention. However, the addition of Fe_2O_3 to kaolinite reduced B retention. The Fe coatings on montmorillonite increased B retention. Aluminum coatings of kaolinite

were more retentive than those on montmorillonite. Perhaps the Al coatings were sealing the innner layer of the smectite.

Sims and Bingham (1968b) were now ready to correlate the Fe and Al content of soils with their B retentive characteristics. Nine soils were reacted with 10 ppm B at pH 6 for 24 hours and the absorbed B calculated. Linear correlation of B retention with extractable Fe and Al_2O_3 were made. Total Fe had a correlation coefficient of only 0.51, but citrate-dithionite extractable Fe had a coefficient of 0.92. The correlation coefficient for HCl and KCl extractable Al_2O_3 were 0.59 and 0.66, respectively. The low correlation between Al and B retention was unexpected, but the authors felt it was the use of the wrong extracting agents which led to the poor correlation.

Okazaki and Chao (1968) confirmed some of the hypotheses of Sims and Bingham (1968b) and Hatcher et al. (1967) with their work on the highly weathered soils of Hawaii. They showed a linear increase in B adsorption capacity with increased soil pH. This relationship had a correlation coefficient, over six soils, of 0.90. Desorption of B for the soils was not so clearly related. The ability of each soil to renew soluble B was examined by varying the extraction time and the temperature of the water, and by successively eluting the soil. The repeated extraction revealed a capacity of each soil to release B after a previous extraction has shown little B release. From this Okazaki and Chao supported the hypothesis of Sims and Bingham (1968b) that B forms more than one reaction product in the adsorption process.

Physiological role of boron in plants

Boron has been the unknown element in plant nutrition for seventy years since Augulhorn (1910) discovered B was necessary for plant growth. Boron has been implicated in sugar transport (Gauch and Dugger, 1953), in RNAase (Cohen and Albert, 1974), in phenolic metabolism (Lewis, 1980), in IAA metabolism (Bohnsack and Albert, 1977), and most recently in membrane function (Pollard, Parr, and Loughman, 1977).

Gauch and Dugger's sugar hypotheses have been all but abandoned since Isbell et al. (1948) showed the proposed complexes between borate and carbohydrate to be theoretically improbable. Weiser et al. (1964) reported B enhanced foliar uptake of sucrose which somewhat supported Gauch and Dugger's idea, but increased absorption does not mean increased transport. Mitchell, Dugger and Gauch (1953) applied 2,4 D with and without sucrose and/or B. The effect of the herbicide on stem curvature was increased up to 150-fold when applied in conjunction with both B and sucrose, but not at all when applied only with B. They concluded that B was influencing sugar transport and only indirectly 2, 4D transport and proposed in their 1953 paper that B may have an effect on membrane permeability.

Cohen and Albert (1974) showed B deficient squash root tip cells would initiate cell division after only six hours of exposure to B, but would not begin mitosis until B was supplied. They monitored DNA production by adding labelled thymidine to the solution surrounding the cells and taking autoradiographs of the cells at different time intervals. They found no addition of the label to the nuclei of cells suffering B deficiency, but the addition of B to the media induced mitosis and the

incorporation of label into the new cells. They concluded the absence of B resulted in the cessation of mitosis and ability to synthesize DNA within 20 hours.

Cohen and Lepper (1977) support the hypothesis of Cohen and Albert (1973) showing that cell elongation of squash roots continued to 72 hours after B deprivation, but cell division and total root elongation ceased after 24 hours.

Birnbaum, Dugger, and Beasley (1977) showed that cotton ovules grown in B deficient media had callose tissue formation and suggested that this is due to a buildup of UDP glucose. Their hypothesis was that B had no effect on RNA, but on the UDP glucose pyrophosphorylase in the DNA pathway. The lack of B allows UDP glucose to be shunted into cellulose production.

Indol acetic acid (IAA) oxidation in squash roots was dramatically reduced 20 fold when B was supplied to the medium (Bohnsack and Albert, 1977). The authors hypothesis was that B deficiency is similar to IAA toxicity since the six to nine hour lag for increased IAA oxidase inducement is similar to the lag produced when IAA is supplied exogenously.

The data are in opposition to the theory proposed by Shkol'nik (1974) who found that IAA oxidase levels in sunflowers drastically declined under B free conditions. Shkol'nik reported that the IAA oxidase in his study was purified of phenolic inhibitors. The purified enzyme gave a much greater level of activity which was unaffected by previous B fertilization. He concluded it was a distinct difference in the amount of inhibitor which led to the difference in activity.

Shkol'nik also reported a difference in phenolic compounds accumulated under B deficient growth. Scopoline and gentisic glycoside are encountered only in B deficient sunflower plants, and there was an increase in both caffeic and chlorogenic acids. Shkol'nik proposed the increased phenol production could affect the membrane permeability, especially the tonoplast. He gave no data to support this hypothesis.

Lewis (1980) has proposed the role of B in shunting carbohydrate into the phenolic pathway is the differentiation between vascular and non-vascular plants. The theory was since the effect of B on membrane permeability would be identical in both vascular and non-vascular plants, the action of B on lignin synthesis from phenols must be the primary role of B in the vascular plant. In his scheme, B bonds with caffeic acid and inhibits the production of caffeoyl-o-quinone, a precursor of the lignin component sinapyl. In support of this theory he points out that bryophytes which do not require B contain primarily p-coumaryl in their lignin, and monocots have fewer sinapyl units in their lignin than dicots.

Pollard et al. (1977) showed B deficient roots of both Vicia faba L. and Zea mays L. to be less capable of absorbing phosphate, rubidium, and chloride than B sufficient roots, but that the addition of B for one hour prior to immersion would bring adsorption levels up to B sufficient ones. These results were supported by applying IAA to root tips and obtaining a similiar decrease in ion uptake. These authors also showed a 35% decline in adenosine tri-phosphatase (ATPase) from membranes of Zea mays L. cells which had been grown in B free media. The ATPase levels were increased by the addition of B 1 hour before homogenation.

Smyth and Dugger (1980) found a similar loss of rubidium uptake with B deficient diatoms. These two groups of researchers oppose Shkol'nik's phenolic effect on membrane theory since the methods they used would eliminate phenolic compounds from the membranes, but, the effects of B were still present. In speculation, Pollard et al. (1977) thought that borate binds directly to the membrane and alters its conformation.

Tanada (1978) showed boron sufficient mung bean hypocotyl tips showed a much quicker response to gravity than B deficient ones. The exposure of these tips to red light enabled B sufficient tips to cling to polarized glass, while B deficient ones lose this ability rapidly. Tanada's hypothesis is B atoms act as a scavenger of electrons released by the membrane. This leaves a positive "hole" in the membrane for movement of negatively charged substances into receptor cells.

Such is the controversy about the roles of B in plants. No one theory enjoys preeminence at this time, but the research is continuing to pursue the role of B in both the phenolic pathway and in the effect of B on membrane permeability.

Boron uptake

Boron is absorbed by plant roots in the undissociated $B(OH)_3$ form (Oertli and Grgurevic, 1975). The barley (*Hordeum vulgare* L.) roots used in the study showed B uptake was linearly related to external B concentration, once sufficient B had been absorbed to maintain the root at 20-22 ppm. The data indicated B was taken into the root cells through diffusion and pH effects were due to the dissociation of the boric acid since B concentration declined with increasing pH and its increase of

the $H_2BO_3^-$ form. Glandon and McNabb (1978) found similiar results with the aquatic duckweed Lemna minor, with the absorpition maxima being 3,200 ppm B.

Methods of B application

Thellier (1962) showed B was absorbed by young radish (Raphanus sativus L.) roots up to 150 ppm, but the cotyledons may contain up to 1,000 ppm. The B was not very mobile after absorption. Boron applied to the foliage was primarily absorbed by the tissue it came in contact with and very little was translocated to the rest of the plant. The small portion that was not fixed tended to move to the adjacent upper leaves and buds.

Aduayi and Adegbite (1979) compared foliar and root applied B on okra (Hibiscus esculentus). They found 4 ppm B supplied to the root in solution culture to be toxic while 4 ppm B applied to the foliage as a spray was the most effective treatment with regard to plant height and flower initiation. Roots supplied B increased foliage concentrations to between 198 to 264 ppm B. Foliage from a no B treatment had 5 ppm B. The foliar supplied B only raised the leaf tissue to 70-120 ppm. Toxic levels for okra foliage are thought to be in excess of 100 ppm B.

Gupta and Cutcliffe (1972) found rutabaga (Brassica naprobrassica L.) responded to soil and foliar applied B with reduced brownheart incidence, but that the 1-2 kg/ha banded treatment was the most efficient method of application at the pH's (5.7 to 6.8) encountered in their study.

Woodruff (1979) applied B in a band, broadcast, and in a foliar drench to soybeans (Glycine max L. Merr.) grown in an Orangeburg sand. He found the drench method most effective in increasing foliar levels of B, but observed no increase in yield, although areas with no B applied produced soybeans with a foliage content of 14 ppm B after one year of the study. concentrations of 20-50 ppm B are considered inadequate for soybeans.

Translocation of B in plants

Boron moves through the xylem as a mass flow (Raven, 1980) with water movement, although the xylem concentration varies from 1 to 65 mM B depending upon the external concentration. The xylem may also differ from the external concentration, although generally only slightly.

Boron has long been thought to be phloem immobile. Boron content of phloem sap is normally less than 1 mM and boric acid at 4 mM is toxic causing callose formation (Crafts and Crisp, 1971). Oertli and Richardson (1970) contrasted the ease of movement of B in the xylem as evidenced by B in water of guttation and the paucity of B in the phloem. They theorized that the high membrane mobility of B allowed it to diffuse out of the phloem back into the xylem where the swifter flow carried it away.

Campbell et al. (1975) found burrs of subclover (Trifolium subterraneum L.) and fruits of peanut (Arachis hypogaea L.) attained B through phloem flow since the fruiting bodies have limited xylem flow. Peanuts which received B only from the fruiting medium contained 10.9 ppm, while those which received B only through the root system contained 11.3 ppm. Those peanut fruit which received B from neither source

contained only 8.3 ppm, a significantly lower amount of B although neither fruit size nor number was reduced. This demonstrated the peanut kernel's ability to obtain B through either the phloem flow or from the soil by absorbing B through the shell as it does with Ca.

Boron content in plants

Hallock and Coffelt (1978) measured leaf and petiole B content of 10 varieties of peanut for two years at pegging and at maturity and found a decline in B from 72 to 46 ppm in leaf blade tissue. Hallock, Martens, and Alexander (1971) had earlier shown a difference between lines of peanuts in B content with the large seeded Virginia types averaging 30 ppm B in leaf blades from central stems and the small seeded Spanish and Valencia types averaging 25 ppm. Hill and Morrill (1975) found addition of 1.12 kg B/ha to the soil increased Spanish peanut foliage from 15 to 61 ppm B and both increased sound mature kernel percentages and decreased internal damage. Jones, Pallas, and Stansell (1980) measured B content of recently matured Florunner peanut leaves over two growing seasons. Boron levels declined from 65 ppm to 30 ppm at mid season, then fluctuated between 30 and 45 ppm one year. The next year levels fell from 50 ppm to 20 with little fluctuation after pegging. Yield the first year was 5,300 kg pods/ha and the second year was 6,050 kg/ha.

Boron deficiency in the peanut was characterized by Reid and York (1958) as water soaked leaves, necrotic leaves and terminals, and prolific growth of woody secondary stems. Boron deficient nuts exhibit hollow heart (a failure of the two halves of the endosperm to meet with

or without a darkening of the tissue). Deficiency levels were proposed as 20 ppm in the foliage and kernels.

Boron content of the seed of peanut is not correlated with percent oil, percent sugar, nor raffinose, sucrose, or stachyose percentages (Walker and Hymowitz, 1972). This implies that the sugar and oil content of the nut is independent of the B nutrition,and the sugar transport theory of Gauch and Dugger (1953) has another disclaimer.

Calcium

General

Calcium (Ca) is a member of the IIA group of alkaline earth metals. Calcium has an atomic radius of 1.74 angstroms in the neutral state and 0.99 angstroms when ionized to its predominant +2 configuration (Mortimer, 1971). Calcium content of surface soils in humid regions varies from 0.01% in Florida sands to 0.97% in Kansas clay (Buckman and Brady, 1969), and constitutes 3.6% of the earth's crust (Mclean, 1975).

Calcium in soil

Calcium in soil is divided into three components: Ca in solution, Ca held by the exchange complex, and non-exchangeable Ca. Plant uptake of Ca in humid region soils is generally from exchangeable Ca, but large additions of limestone ($CaCO_3$) or gypsum ($CaSO_4 \cdot 2H_2O$) increase levels of solution Ca depending on the solubility of the material. Calcium carbonate has a solubility product (K_{sp}) of 4.7×10^{-9} while gypsum has a K_{sp} of 2.4×10^{-5} (Bennett and Adams, 1972). Bennett and Adams (1972)

showed that the activity of Ca^{+2} in solution was governed by the solubility product of gypsum, when application was of sufficient magnitude, regardless of soil type.

Figure 1 (Lindsey, 1979) shows the solution concentration maintained by limestone, gypsum, and "soil Ca" at a soil atmosphere CO_2 concentration of 300 ppm. Calcium forms many ion pairs in solution, but only Ca^{+2} is absorbed by plants (Maas, 1969) and the ion predominates in solution at pH less than 8.2 (Lindsey, 1979). Figure 1 shows that limestone maintains a higher activity of Ca^{+2} than gypsum in acid soils, while gypsum maintains higher levels in soils.

Calcium nutrition of the peanut plant

Ever since Bledsoe et al. (1949) proved the peanut gynophore absorbed Ca from the surrounding medium and Weirsum (1951) showed no flow through the xylem to the buried fruit, growers have been supplying large amounts of Ca to the plant by liming or as gypsum in the pegging zone. Many researchers (Hallock and Allison, 1980, Hickey et al. 1973, Walker et al. 1979, Adams and Hartzog, 1979, Walker and Keisling, 1978, Walker et al., 1976) have found that responses to Ca supplements varied with the variety of peanut.

Coldwell and Brady (1945) showed that large-seeded Virginia type peanuts required more Ca than the Spanish type. Walker et al. (1976) showed Florigiant and NC Fla 14, but not Florunner peanuts responded to 1,121 kg/ha gypsum when soil test levels were 215 kg Ca/ha. Walker and Csinos (1980) showed that five varieties of peanut, Florunner, Early Bunch, Florigiant, Tifrun, and Ga 194 Va, responded to additional Ca

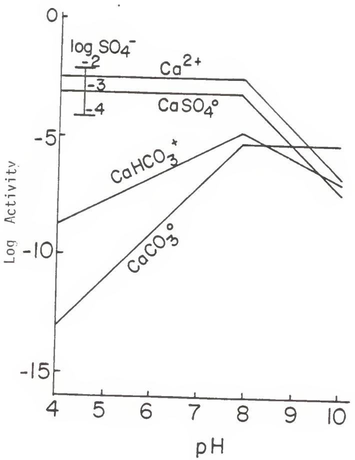


Figure 1. Calcium species in solution in equilibrium with "soil Ca" and calcite ($CaCO_3$) (Adapted from Lindsay, 1979)

when soil test levels were 356 kg Ca/ha, but not when it was 752 kg/ha. Seed quality was also increased by the Ca supplement on the low Ca soil.

Hallock and Allison (1980) obtained significant responses by Florigiant peanuts when gypsum was added to soils containing 560 kg/ha extractable Ca. Hickey et al. (1973) showed Florunner responded to limestone additions when the soil contained 51 ppm extractable Ca, but obtained no response to gypsum on the same soil one year later when the soil test value was 147 ppm.

Bracho et al. (1971) obtained no response to Ca additions by either Florunner, Florigiant, or NC 17 when soil Ca levels were 250 to 296 ppm. Varnell et al. (1976) got no response by Florunner to gypsum even though the soil Ca level was 75 ppm. In a series of experiments in Alabama Hartzog and Adams (1973, Adams and Hartzog, 1979, 1980) presented evidence to support 250 pp2m Ca as the level at which peanuts should respond to Ca supplements. Two of the more recent research projects were with the Florunner peanut variety but the earlier work was with many different varieties of peanut. This level of "sufficient" soil Ca is interesting since a compilation of data from the University of Florida's Soil Testing Laboratory shows overall only 20% of tested Florida soils contain less than 448 kg Ca/ha extracted with Mehlich 1 (double acid) (Rhue and Sartain, 1978).

Wolt and Adams (1979) found the ratio Ca/(Ca + Mg + K) to be more important in both vegetative and reproductive growth of Florunner peanuts in nutrient solution than the amount of Ca contained in the solution. They found a ratio of 0.25 to be highly correlated with the maximum fruit weight/cavity while only a ratio of 0.10 was needed for vegetative growth. This is in accordance with field observations of Bledsoe et al.

(1949) that peanut plants showing no distress in the vegetative portion will fail to bear unblemished fruit.

Physiological roles of Ca

Calcium's primary role in the plant is to maintain membrane integrity (Epstein, 1972). Hale (1978) showed Argentine peanut pegs exuded more sugar when placed in 10 mg/l Ca^{+2} than when placed in 50 mg/l. This may explain the contention of Garren (1964) that increased Ca reduces the incidence of pod rot. If the pegs are deficient in Ca the increased sugar surrounding the gynophore would encourage fungal growth. Calcium is necessary to maintain the selectivity of the K uptake mechanism (Epstein, 1972). Interestingly, Ca has been shown to inhibit ATPase in peanut (Brown et al. 1965). Since it is ATPase which is thought to be involved in K transport, the inhibition by Ca may explain the pronounced antagonism between Ca and K in the nutrition of the peanut.

Much of the Ca found in plants is located in the cell wall. Its role as a "cementing agent" is currently under debate (Christiansen and Foy, 1979).

Calcium uptake

Calcium is thought to be absorbed by the plant root passively in the meristematic region just behind the root tip (Clarkson et al., 1968). Maas (1969) found Ca uptake to be active at low levels of Ca in the external solution, but passive when Ca exceeded 5 mM. Davidian and Salsac (1978) were in agreement with Maas' work with corn when they found Ca uptake was sensitive to metabolic inhibitors when the Ca concentration was 0.2 mM.

Calcium movement across animal and bacterial membranes is known to be ATPase linked (Tada et al., 1978) and respiration coupled (Barnes et al., 1978). Little work has been done in plants. The active transport of Ca across sarcoplasmic reticulum is mediated by the addition of tetraphenyl borate (TPB) (Caroni et al., 1977). The sarcoplasmic reticulum is a continuous system of vesicles, tubules, and cisternae enclosed by membranes (Tada et al., 1978). These structures accumulate Ca by transporting it across the membranes with ATPase as a carrier into the vesicles. Although no comparable strucutre exists in plants, the ability of TPB to mediate the transport across membranes is thought to be due to the complexing of the TPB^+ with the membrane and may be applicable to any biological membrane.

Calcium transport in plants

The movement of Ca in plants is almost exclusively through the xylem. Singh and Jacobson (1977) found no Ca in the cortex of corn roots, but large concentrations of Ca in the xylem parenchema cells. They hypothesize that Ca moves through the xylem parenchema cells in a metabolically mediated fashion. This is in conflict with previous theories (Moore et al., 1961) that proposed Ca moved readily through roots by surface migration along cell walls. The rapid accumulation of radioactive Ca by the xylem parenchema cells with no Ca in the mature duct cells shows that living cells are necessary for Ca movement from the surface of the root to the xylem (Singh and Jacobson, 1977). Movement in the xylem is due to ion exchange up the column of the cell walls (Bell and Biddulph, 1963). Calcium moves up the xylem column in response to increased cation exchange capacity (CEC) of the column at

upper levels. Anything which reduces the CEC of the upper column will reduce the movement of Ca in the plant. Manganese toxicity decreased Ca movement into the apparent free space of bean (*Phaseolus vulgaris* L.) leaves (Horst and Marschner, 1978). Calcium movement in the xylem is also regulated by the transpiration flow. Michael and Marschner (1962) showed Ca movement to leaves is less under conditions of high humidity.

Calcium movement in the phloem is negligible. Marschner and Richter (1974) found radioactive Ca applied to upper roots of corn was not translocated to the root tip, only to the upper plant. The mechanism of Ca exclusion from the phloem is not well understood. Van Goor and Wiersma (1974) hypothesized calcium phosphate formation, but it was pointed out by Epstein (1972) that there was no phosphate transport problem in phloem and no $CaHPO_4$ had been found. Epstein proposed the reason for Ca exclusion was the structureless properties of the phloem tube. Marschner proposed the cells around the phloem are very efficient accumulaters of Ca and remove all of it from the sieve tubes.

Calcium content of plants

Legumes are generally much higher in Ca than graminaceous plants, with monocots generally having less than 1% and dicots having 2% (Loneragan and Snowball, 1969).

Peanut foliage contains from 1.4% to 3.15% Ca (Hickey *et al.*, 1973, Hallock and Coffelt, 1978). The bunch Virginia type peanuts are generally higher in foliar Ca than the Spanish, Valencia, or runner peanuts, but the differences are subject to sampling error since the Ca content of the upper leaves is higher than that of the lateral branches

and the runner and Spanish types have a less well defined main stem than the Virginia types (Hallock *et al*., 1971). Hallock and Coffelt (1978) stated that Early Bunch peanuts tend to have the highest Ca and B content of eight Virginia type varieties they studied.

Cox *et al*. (1976) reported that peanut seed must contain 420 ppm Ca to ensure proper germination. This sufficiency level was supported by Hallock (1980). Walker and Hymowitz (1972) surveyed five varieties of peanut and found seed Ca ranged from 0.08 to 0.80%. Hallock and Allison (1980) found that Ca in Florigiant with different fertilization ranged from 270 to 620 ppm Ca. Bracho *et al*. (1971) found that the seed of Florunner, Florigiant, and NC 17 varieties contained 0.08% to 0.10%. Wolt and Adams (1979) recommended that the Ca/(Ca + Mg + K) ratio should exceed 0.28 for proper seed formation.

Calcium and Boron Interactions

Since Ca and B are both phloem immobile, except in certain cases, several researchers have tried to link the two elements in their effects on plant metabolism. Eschrich,(1975)proposed that B is a complexing agent for the glucose precursors of callose tissue. If more than 5 ppm B enters the phloem, callose forms. Hydrated pure callose is impermeable to water. Treatment of callose with 10^{-4}M $CaCL_2$ rendered the callose permeable and produced a CaP salt.

This is a satisfactory way to explain the Ca/B ratio theory of Gupta and Cutcliffe (1972). They found a Ca/B ratio of less than 400 was necessary to prevent the incidence of "brown heart" in rutabaga (*Brassica naprobrassica* L.). Under the theory of Crafts and Crisp (1971) the occurrence of excess B in the phloem induced callose which

could be alleviated by Ca additions. If B is deficient, the carbohydrate is shunted into lignin production which complexes Ca (Lewis, 1980).

Blatt (1976) found increasing the B fertilization of strawberries increased leaf Ca until maximum growth was obtained. Once B became toxic enough to decrease growth, Ca content of the leaves declined. Miller and Smith (1977) and Fox (1968) showed increasing B fertilization of alfalfa decreased leaf Ca.

Cox and Reid (1964) showed Ca and B deficiency in peanut seed to be separate. The lack of Ca in the seed induced a dead embryo commonly referred to as "black plumule", while B deficiency induced a lack of endosperm formation with or without brownish discoloration, commonly called "hollow heart." Addition of B had no effect on seed Ca and vice versa. It is note worthy that an increase of seed Ca from 0.030 to 0.039% reduced black plumule incidence from 35 to 10%.

Seed Pelleting

The limestone pelleting of legume seed is a well established practice on forage legumes (Brockwell, 1963). Reddy and Tanner (1980) state that the currently used granular inoculant is the superior method of peanut inoculation since "...using sticker (sugar solution, milk, water) may cause damage to the seed coat and reduce germination". Reddy and Tanner also state that 12 kg granular inoculant per ha did not prove superior to 2 kg powdered peat inoculant per ha on Comet peanuts in total N, but granular peanut inoculant's use was justified since its use "protects the rhizobia from heat and desication as a result providing

sufficient numbers of bacteria to the rhizosphere". Gull et al. (1963) found pelleting of seed with inoculum increased longetivity of rhizobia and resulted in faster inoculation of pasture species.

Peanut Varieties used in these studies

The Florunner variety was released in 1969 and now is planted on the majority of peanut land in the U. S. A. It is a runner type peanut derived from a 1960 cross between Early Runner and Florispan (Norden et al., 1969).

Early Bunch is a Virginia type peanut which is a composite of five sister lines. Early Bunch was shown to out yield Florunner by 141 kg/ha over five years in Florida and by 5% in Georgia (Norden et al., 1977).

MATERIALS AND METHODS

Soil analyses were done according to Mitchell and Rhue (1979). Calcium, Mg, and K were extracted with Mehlich 1 (double acid) and determined by atomic absorption spectroscopy. Phosphorus was also extracted with Mehlich 1 and determined by the ammonium molybdate-ascorbic acid method on a Technicon Autoanalyzer II. Boron was extracted by boiling 10 g of dried, seived soil in 50 ml of distilled deionized water for five minutes. The solution was filtered through Whatman #42 filter paper and B was determined by the Azomethine-H method of Sippola and Ervio (1977), modified by using no charcoal and by using the commercially available Azomethine-H from the Pierce Chemical Company of Rockford, ILL instead of manufacturing the reagent in the laboratory.

Tissue analyses were obtained by ashing 0.5 g of oven dried tissue in a Coor's porcelain evaporating dish for 2 hours at 200 c and then raising the muffle furnace to 450 C and continuing the ashing overnight. The resultant ash was dissolved in 10 ml 5 N HCl, evaporated to dryness on a hot water bath, redissolved in 0.1 N HCl, and filtered through Whatman #42 filter paper with 0.1 N HCl to 50 ml. Calcium, Mg, K, P, and B were determined as in the soil extracts. Nitrogen was determined by semi-micro-kjehldahl on a separate 0.5 g sample. All glassware was B-free and samples were stored in polyethylene bottles.

Foliage samples were ground to pass a 60 mesh screen in a stainless steel Wiley mill. Kernels were ground in a stainless steel blender to a chunky consistency.

The sticking agent for seed pelleting in all experiments was prepared by adding 100 g gum acacia (gum arabic) to 230 ml distilled deionized water, heating the mixture with stirring until a clear solution was obtained, and allowing the solution to cool. The sticker was adjusted to pH 7 with reagent grade calcium carbonate and Nitragin peat base inoculum type EL was added. For treatments requiring fertilizer reagent grade chemicals were used. The peanut seed were stirred with the sticking agent in a polyethylene bucket "mixing chamber" and the seed thoroughly coated. Precipitated reagent grade $CaCO_3$ was added as a drying agent and the seed were allowed to cure overnight before planting the next day.

Field Experiment 1 - Calcium Source and Rate Study on Early Bunch Peanuts

Early Bunch peanuts were planted 12 June, 1977, in an Arredondo fine sand (loamy, siliceous, hyperthermic Grossarenic Paleudult) on the Green Acres Agronomy Farm, Gainesville, Florida. Chemical analysis data of prefertilization soil samples from the site showed the following: marginal pH 5.3; adequate Mo and B, 0.1 and 0.6 ppm, respectively; high Ca 454 ppm; and low K, P, and Mg, 55, 51, and 50 ppm, respectively. Basic analyses were compared to standard fertilizer recommendations of the Institute of Food and Agricultural Sciences, University of Florida. Three hundred kg/ha of 4-8-16 mixed fertilizer was disced into the soil pre-plant to provide 12-10-38 kg N-P-K/ha.

The experimental design was a randomized complete block with six replications with each treatment containing 4 rows 6 m long and 90 cm

apart. Treatments were $CaSO_4 \cdot 2H_2O$ (gypsum), $CaCl_2$, or pelletized limestone ($CaCO_3$) applied over the row 27 June to supply 78, 156, or 312 kg Ca/ha from each source with three 0 Ca check plots in each replication. Top leaf samples were taken 29 June and 25 August. Peanuts were dug 1 September through 6 September. Nuts were dried in forced air ovens to 9% moisture and graded according to State and Federal Standards. Soil samples were taken 7 September.

Field Experiment 2 - Seed Pelleting as a Means of Supplying B and Inoculum to Florunner Peanuts

Florunner peanuts were planted in an Arredondo fine sand on 30 June, 1977 at the Green Acres Agronomy Farm. Chemical analysis of prefertilization soil samples from the site showed the following: pH 4.9, which is too acid for peanut growth; adequate B and Mo, 0.6 and 0.1 ppm, respectively; low Mg and K, 51 and 55 ppm, respectively; and very high Ca and P, 521 and 290 ppm, respectively. The high Ca level somewhat precluded the need for liming to supply Ca.

The experimental design was a split plot with gypsum rates as main plots and seed treatments as subplots with five replications. Gypsum applied over the row at first bloom supplied either 0, 46, 92, or 184 kg Ca/ha. Seed treatments were: pelleted seed with inoculant and Na_2BO_4 to provide 23 or 92 mg B/kg seed; seed pelleted with inoculant; and an unpelleted, uninoculated check. Stand counts were taken 11, 14, and 21 July and top leaf samples were taken 21 July, 18 August, 15 September, and 4 November. Peanuts were dug 4 November and treated as in field experiment 1.

Laboratory Experiment 1 - Comparing Methods of B Determinations

Methods of determining B, Azomethine-H (Sippolo and Ervio, 1977) and carmine (Gabriels and Keirsbulck, 1974) were compared using either quartz crucibles or Coor's porcelain evaporating dishes. Subsamples of four large peanut foliage samples from field experiments were analyzed. Peanut foliage with, and sucrose with and without boric acid to supply 2,000 ppm B were also analyzed. Each determination was made 10 times. Ashing was as previously described.

Field Experiment 3 - Effects of Prior Cropping History, Foliar Applied B, and Seed Applied Mo and W on Early Bunch Peanuts

Chemical analysis of prefertilization soil samples from the site showed the following: adequate pH 5.7; adequate B and Mo 0.4 and 0.1 ppm, respectively; low K and Mg, 56 and 51 ppm, respectively; and high Ca and P, 424 and 484 ppm, respectively. Main blocks of the experiment were adjacent strips of Arredondo fine sand which had been either in bahiagrass or weedy fallow for the previous five years. There was no significant difference between the soil test values for soils beneath the bahiagrass or the soil which had been left fallow, so the data presented is an average of the two blocks.

The experimental area located on the Green Acres Agronomy Farm was broken to 15 cm with a moldboard plow 2 May, 1978, and 300 kg/ha 4-8-16 disced on 4 May. Benefin was applied 8 May and Early Bunch peanuts were planted 10 May. The experimental design was a split-split plot with main blocks being fallow and bahiagrass prior cropping history. Split plots were 1 kg B/ha applied in five foliar applications of boric acid

(H_3BO_3) and no B. Split-split plots were single rows of seed pelleted with either inoculant alone, inoculant plus 34 mg Mo/kg seed from ammonium molybdate, inoculant plus 34 mg W/kg seed from sodium tungstate incorporated in the pellet, or inoculant in the pellet plus 10 kg W/ha from sodium tungstate added over the row 25 May. Tungsten was added as a negative factor since it has been shown to be a competitive inhibitor of Mo with nitrogenase (Callis and Wentworth, 1977). Dyanap (naptalam + dinoseb) and alachlor were applied 18 May at cracking and stand count was taken 8 June. Boron was applied with Bravo 25 June, 17 July, 15 August, 24 August, and 30 August. Gypsum to supply 136 kg Ca/ha was applied over the row 7 July at first bloom. Plots for B contained 4 rows 10 m long and 1 m apart. Seed were planted 15 cm apart in the row. Peanuts were dug 25 September and treated as in other field experiments.

Laboratory Experiment 2 - Effect of Seed Treatment on N Fixation by Early Bunch Peanuts

In this experiment N fixation was estimated by determining acetylene reduction to ethylene. Root systems were dug from each of the four seed treatments of field experiment 3. Six whole root systems from each seed treatment were placed in Dow Zip Loc bags in the field and placed on ice. They were transported to the laboratory as quickly as possible. The air was removed from the bagged root systems by suction and replaced with a mixture of 90 ml air and 10 ml acetylene. The root systems were allowed to react with this gas mixture for exactly one hour at 23 C and a sample was then drawn from the bag and placed in an evacuated test tube. The sample was analyzed for ethylene by gas chromatography.

Field Experiment 4 - Methods of Supplying B at Two Levels of Gypsum to Florunner Peanuts

Florunner peanuts were planted 6 May, 1978 in a Red Bay fine sandy loam (fine loamy, siliceous, thermic, Rhodic Paleudult) at the West Florida Research Center, Jay, Florida. Chemical analysis of prefertilization soil samples from the experimental site showed the following: adequate pH value of 5.8; high B and Ca, 1.5 and 422 ppm, respectively; and low Mg, K, and P, 24, 28, and 20 ppm, respectively. This soil had the highest hot water soluble B content of any in this report.

The experimental design was a randomized complete block with four replications. Treatments were a factorial arrangement of 2 kg B/ha broadcast on the soil preplant, 1 kg B/ha foliarly applied at pegging, and five applications of 0.2 kg B/ha foliarly applied in two week intervals, with each B treatment receiving either 0 or 188 kg Ca/ha from gypsum at pegging. The check areas received neither B nor Ca for a total of seven treatments. Foliar samples were taken 10 June and 12 July and peanuts were dug 15 September and dried to 13% moisture.

Greenhouse Experiment 1 - Effect of Ca and B Applications to Soil on Ca Uptake by Early Bunch Fruit

Lakeland sand (thermic, coated Typic Quartzipsamment) was brought in from a virgin site near Live Oak, Florida. Chemical analysis data of the soil were as follows: marginal pH 5.6; low hot water soluble B, 0.15 ppm; and low Mehlich 1 extractable Ca, Mg, P, and K, 163, 8, 46, and 37 ppm, respectively. The soil was placed in a polyethylene lined tray 3.1 m by 0.9 m by 30 cm and divided into six compartments using fiberglass sheets. Six parafin coated aluminum tubes 9.4 cm by 30 cm

were embedded in each compartment. These physical arrangements were for a split plot experiment with three replications. Main plots were Ca, 0 and 232 kg/ha, from gypsum applied to the soil outside of the tubes. A factorial arrangement of Ca levels (0 and 232 kg/ha) and boron rates (0, 1, and 2 kg/ha from boric acid) was applied to the soil inside the tubes as split plot treatments. The tray was watered daily with distilled water and fertilized with one-half strength Hoaglands solution without Ca. Three Early Bunch peanut seed were planted in each tube and later thinned to two plants per tube after emergence. The gynophores from each plant were allowed to embed only in the soil outside the tubes. Gynophores were harvested for analysis after 50% had reached a diameter of 2 cm.

Field Experiment 5 - Effects of Seed Pelleting with Inoculum and Mo, Soil Applied Gypsum, and Foliar Applied B on Early Bunch Peanuts

Early Bunch peanuts were planted on an Orangeburg sandy loam (fine loamy, siliceous, thermic Typic Paleudult) at the Agricultural Research Center, Jay Florida. The chemical analysis of prefertilization soil samples showed the following: marginal pH of 5.5; low Ca, and K values, 138 and 61 ppm, respectively; very low Mg and P, 11 and 11 ppm, respectively; and adequate B and Mo, 1.1 and 0.3 ppm, respectively.

The experiment was a split plot with five replications. The main blocks were a factorial arrangement of four rows 90 cm apart and 5 m long with Ca from gypsum applied at 0 or 242 kg/ha and B from boric acid foliarly applied at 0, 1 kg/ha at pegging, and five applications of 0.2 kg/ha beginning at pegging. Split plots consisted of single rows of

seed either unpelleted, pelleted with inoculant only, inoculant plus 34 mg Mo/kg seed, or inoculant plus 68 mg M/kg seed from ammonium molybdate.

Stand count was taken 23 June, 1979, four weeks after the 21 May planting. Gypsum was applied 23 June after stand counts were taken and the B was also applied on that day. The other four B applications were at two week intervals after that day. Yield data was lost due to severe wind and rain at harvest.

Statistical Analysis

Analysis of variance were computed for all field, greenhouse, and laboratory experiments. Duncan's multiple range tests were used to compare differences between treatment means.

RESULTS AND DISCUSSION

Calcium Source and Rate on Early Bunch Peanuts

Chemical analysis of leaf samples taken 29 June and 25 August are presented in Table 1. Treatments had no effect on leaf N, P, K, or Mg, but leaf Ca was strongly influenced by Ca additions (Table 2). The higher values for 29 June may be an artefact of the fertilizer applied over the top of the plant two days previously, but effort was made to obtain samples not surface contaminated and the leaf samples were rinsed in distilled water before grinding. Table 2 shows the areas receiving no Ca were significantly lower in leaf Ca than all others. Samples from the 78 kg Ca/ha gypsum and limestone treatments had significantly less Ca than the 312 kg Ca/ha gypsum treatment. The latter was significantly lower than the 312 kg Ca/ha rate from $CaCl_2$. By 25 August the Ca concentration probably represents the true influence of soil applications of Ca and shows that plants receiving no Ca were still significantly lower in leaf Ca than all the Ca fertilized ones. Only the 312 kg Ca/ha from limestone treatment increased the leaf Ca concentration significantly above the 78 kg Ca/ha rate, with the highest gypsum and $CaCl_2$ treatments being intermediate.

Figure 2 shows the effect of various rates and sources of Ca on pod yield of Early Bunch peanuts. Statistical analysis of the data indicated that there was no significant difference in yield levels with a coefficient of variation (C. V.) of 21%. At the 78 kg Ca/ha rate, gypsum had the lowest pod yield of all treatments, producing 4268 kg/ha. Gypsum also had the highest yield, 5268 kg/ha, at the 312 kg Ca/ha rate.

Table 3 shows the effect of Ca source and rate on Sound mature kernels (SMK). Overall SMK was 59% with no significant differences among treatments. There was little incidence of plumule or other

Table 1. Early Bunch peanut leaf content of N, P, K, and Mg averaged across Ca treatments on Arredondo fs, 1977

Date	% N	% P	% K	% Mg
29 June	2.75	0.25	2.83	1.02
25 August	1.58	0.20	2.48	0.85

Table 2. Early Bunch peanut leaf content of Ca as influenced by Ca source and rate, 1977

Source	Rate	27 June	25 August
	0	2.12a*	2.20a*
Gypsum	78	2.88 b	2.44 b
	156	2.97 bc	2.57 b
	312	3.21 c	2.62 bc
$CaCl_2$	78	2.99 bc	2.49 b
	156	3.71 d	2.47 b
	312	3.95 d	2.62 bc
$CaCO_3$	78	2.75 b	2.46 b
	156	2.89 bc	2.59 b
	312	3.45 cd	2.93 c

Means in a column not followed by the same letter are different at the 5% level of significance by Duncan's multiple range test.

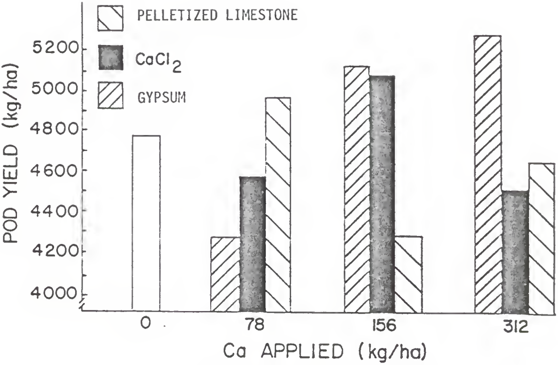


Figure 2. Effect of Source and rate of Ca on pod yield of Early Bunch peanuts grown on Arredondo fs, 1977.

Table 3. Effect of Ca source and rate on seed quality and Ca content of Early Bunch peanuts grown in Arredondo fs, 1977.

Calcium Source	Rate kg/ha	SMK	ELK	Shelling	Ca in seed ppm	wt/100 seed g
		----------%	-------------			
none	0	60.0	53.8a*	74.5	410	103.2a*
Gypsum	78	60.8	49.9 b	74.1	405	102.6ab
	156	59.4	53.3a	74.6	415	104.6a
	312	59.0	52.5a	75.5	420	105.2a
$CaCl_2$	78	55.5	54.1a	74.0	425	104.1a
	156	62.4	54.3a	74.3	440	105.5a
	312	59.1	51.9ab	74.1	445	103.1a
$CaCO_3$	78	59.6	54.6a	74.5	400	102.5ab
	156	55.9	47.4 b	74.6	420	98.3 b
	312	60.3	50.6ab	74.4	425	102.4ab

*Means in a column not followed by the same letter are different at the 5% level of significance by Duncan's multiple range test.

Table 4. Effect of Ca source and rate on soil test values* from post harvest soil samples on Arredondo fs, 1977.

Source	Rate	pH	Ca	Mg	K	P
			ppm			
none	0	5.8	525	43	45	52
Gypsum	78	5.7	532	40	44	51
	156	5.7	522	38	42	52
	312	5.6	547	39	45	49
$CaCl_2$	78	5.7	529	41	40	48
	156	5.7	538	37	41	53
	312	5.7	542	37	43	52
$CaCO_3$	78	5.8	537	42	44	52
	156	5.9	549	41	43	56
	312	6.0	575	39	42	49

*Extracted with Mehlich 1 (0.05 N HCl + 0.025 N H_2SO_4)

internal damage for any treatment. Shelling percentages averaged 74.5% with no signifacant differences due to Ca additions. Surprisingly, there was no significant difference in kernel Ca concentration, with an average of 420 ppm. Seed weight and percent extra large kernels (ELK) were similar except the treatment receiving 156 kg Ca/ha from limestone was significantly less than the majority of the treatments. The 78 kg Ca/ha rate of gypsum was also significantly less in ELK, however the weight of seed was intermediate to all other values. SMK was also low for these two treatments, although not significantly so.

Analysis of soil samples taken at harvest showed no effect of Ca additions on pH or Mehlich 1 extractable Mg, K, or P (Table 4). The addition of 312 kg Ca/ha from limestone increased soil Ca by 50 ppm, but this was not significant. Differences from Ca sources and rates may have been obscured by the addition of 2.9 kg Ca/ha with each cm of irrigation water from shallow wells.

Effect of Gypsum Additions and Seed Pelleting as a means of supplying B and Inoculum on Florunner Peanuts

The site had not been limed for many years and had been in weedy fallow for several years prior to the experiment. Florunner peanuts were planted extremely late on 30 June. The experimental site was chosen with the assurances that the area was uhlimed and we had an erroneous assumption that this would lead to low extractable Ca levels in the soil.

Figure 3 shows the effect of seed treatment on the emergence of seedlings. At all three observations the 92 mg B/kg seed treatment significantly reduced emergence below that of the other three treatments. The stand was 75% for the three non-affected treatments at the end of three weeks, but the high B additions had only a 61% stand. More

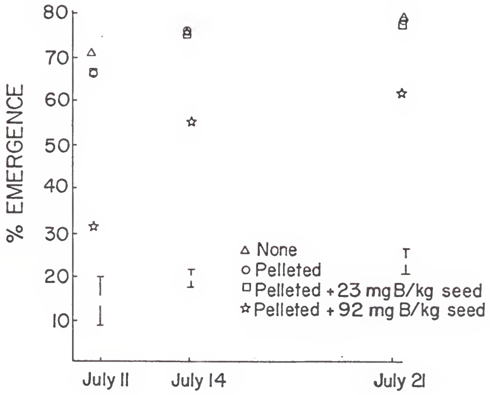


Figure 3. Effect of limestone pelleting and B additions on emergence of Florunner peanut seedlings in Arredondo fs, 1977.

noticeable is the delay in emergence. The high B treatment had only 32% emergence at 12 days, while the other treatments were within 10% of their final stand 12 days after planting. At 15 days, the three treatments with the better emergence had come to within 3% of final stand, while the high B treatment was at 54% stand.

Figure 4 shows the B concentration of the newest leaves throughout the growing season. The data for three-week-old leaves shows that the treatment receiving 92 mg B/kg seed had a leaf B concentration of 312 ppm. This is in the toxic range, while the 23 mg B/kg seed had a leaf B concentration of 58 ppm. The seed receiving no B produced seedlings containing less than 20 ppm B. The B concentration of the new leaves from the high B rate remained significantly higher than those that did not receive B for 11 weeks. By the fifteenth week of the study, all new leaves contained the same level of B regardless of B treatment.

Figure 5 shows the effect of gypsum additions on Ca content of new leaves. Only in leaves gathered during the seventh week, one week after gypsum was applied over the row, did gypsum additions significantly effect the Ca concentration. By the end of the experiment, all treatments averaged 2.5% Ca, with no differences in Foliage Ca concentrations from Ca additions.

The only element in new leaves affected by treatments was the one applied, e.g. Ca and B. Figure 6 shows the N, P, and K concentrations of the new leaves through the season. The slight decline of K concentration at seven weeks is probably due to ion antagonism from the gypsum additions one week earlier.

Table 5 shows the effect of B and Ca additions on seed quality. Neither element significantly altered the quality of kernels, but there

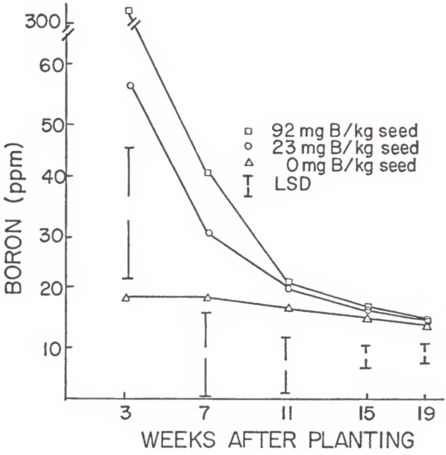


Figure 4. Effect of B additions to the seed pellet on B content of new leaves of Florunner peanut grown in Arredondo fs, 1977.

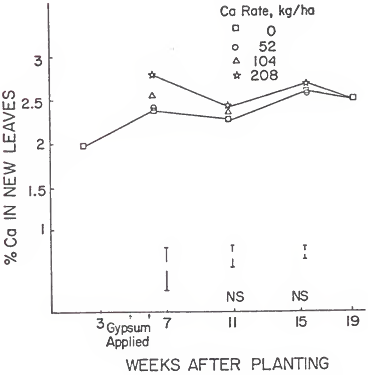
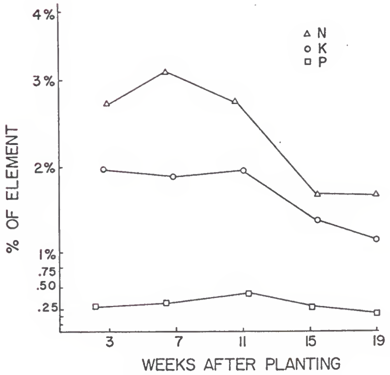


Figure 5. Effect of Ca additions on Ca content of new leaves of Florunner peanut grown in Arredondo fs, 1977.



(concentration)

Figure 6. Nutrient content of new leaves of Florunner peanut grown in Arredondo fs, 1977.

Table 5. Effect of seed treatment and Ca additions on seed quality of Florunner peanuts on Arredondo fs, 1977.

Seed Treatment	Ca Rate kg/ha	SMK	ELK	Shelling	wt/100 seed g
		-----------%---------			
none	0	73	22	77.1	76.8
	52	71	23	76.4	76.4
	104	73	24	76.1	76.3
	208	71	21	75.8	75.9
Pelleted	0	69	24	77.2	77.4
with inoculum	52	73	24	76.3	77.7
	104	69	23	77.0	76.4
	208	68	22	76.7	75.8
Pelleted with inoculum	0	73	23	74.1	76.5
+	52	77	24	77.0	78.3
	104	72	22	71.2	77.2
23 mg B/kg seed	208	72	22	71.2	77.2
Pelleted with inoculum	0	70	21	70.7	76.4
+	52	68	21	69.9	76.0
92 mg B/kg seed	104	67	20	69.4	75.6
	208	67	20	68.0	74.2

was a trend. The highest rate of Ca and the high rate of B decreased seed weight from 0.783 g to 0.742 g, the SMK from 73% to 67%, and the shelling percentage from 77% to 68%. Figure 7 shows the effect of B and Ca additions on pod yield. The non-pelleted seed averaged 2111 kg/ha, the pelleted 2037, the pelleted plus 23 mg B/kg seed 2028, and the seed pelleted with 92 mg B/kg produced significantly less than the other seed treatments, only 1314 kg/ha unshelled pods. Figure 7 illustrates the interaction between increasing gypsum and B rates. These differences are significant at the P = 0.16 level of significance. The 208 kg Ca/ha-92 mg B.kg seed treatment produced only 1200 kg pods/ha and the 104 kg Ca/ha-92 mg B/kg seed treatment produced 1361 kg pods/ha, while all other treatments produced at least 1600 kg pods/ha. This experiment's highest yielding treatment was 23 mg B/kg seed with 52 kg Ca/ha. It produced 2418 kg pods/ha. This experiment was not irrigated and experienced drought conditions for most of its duration.

<u>Comparing Methods of B Determination</u>.

Table 6 shows the effect of crucible type and method of B determination on the B concentration of peanut foliage from four treatments of two field experiments with and without added B. There were no significant differences between the two differennt methods of analysis. The only values approaching significance were the carmine determined foliage samples of the 92 mg B/kg seed treatment which had one replicate which read 265 ppm. The variations between determinations except for this one were less than 5%. The calibration curve for the Azomethine-H was a straight line from 0 to 2 ppm, but lost linearity above that value. Consiquently tissue which contained above 200 ppm B had its solution diluted 1:10 with distilled, deionized water.

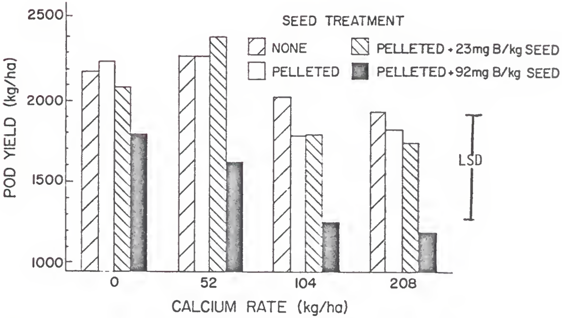


Figure 7. Effect of seed treatment and Ca additions on pod yield of Florunner peanuts on Arredondo fs, 1977.

Table 6. Influence of crucible type and analytical method on B determination of peanut foliage and sucrose.

	Method of Analysis			
	Azomethine-H		Carmine	
Crucible type	Porcelain	Quartz	Porcelain	Quartz
	----------------B ppm----------------			
Source of Sample				
312 kg Ca/ha from $CaCO_3$ Field Expt. 1.	28.7±0.37*	29.0±0.35	29.1±0.36	29.2±0.37
0 Ca treatment, Field Expt. 1	35.3±0.29	35.2±0.33	35.1±0.31	35.4±0.34
92 mg B/kg seed, treatment, Field Expt. 2	312 ± 2.37	312 ± 3.01	306±16.27	312 ±2.48
23 mg B/kg seed treatment, Field Expt. 2	54.1±0.56	55.2±0.62	54.3±0.68	54.8±0.73
23 mg B/kg seed Treatment, Field Expt 2 + 2000 ppm B	2066±18.22	2078±17.61	2064±18.62	2075±19.30
Sucrose + 2000 ppm B	1993±19.36	2002±19.48	1994±22.01	2009±21.08

* one standard deviation

The two crucible types also had no effect on B determination, but the quartz crucibles were higher in most instances. The overall C. V. for the 240 determinations was 3.3%.

The Azomethine-H method required slightly less time to prepare samples for analysis, but the one hour development time required for both methods masked any time saved. However, the Azomethine-H method is simpler in that only two solutions are added to the aliquot, while the carmine method requires additions of four different liquids. Also the Azomethine-H was read on a Baush and Lomb Spectronic 20 while the carmine required a more sophisticated spectrofluorimeter. Either method is preferable to the older carmine or cucurmine methods which require addition of concentrated sulfuric acid.

Effects of Prior Cropping History, Foliar Applied B, and Seed Applied Mo and W on Early Bunch Peanuts

There was a significantly less dense stand of four-week-old seedlings on the land which had been in bahiagrass (Table 7). The 15 cm depth of incorporation was not enough to completely bury the bahiagrass stolons and a trashy seedbed resulted. The pelleted only seed and the treatment which received tungsten (W) in the soil had the same emergence, which should be expected since the seed were treated the same.

There was a color response to Mo by 19 June. New leaves sampled 19 June showed Mo fertilization had increased N concentration to 5.2%, while W fertilized plants averaged 5.0% regardless of seed or soil application of W. Check plants averaged 4.9% N. These differences were not statistically significant. Figure 8 shows the N concentration of the newest leaves throughout the growing season. At no time did B have

Table 7. Influence of prior land use and seed treatment on Early Bunch peanut emergence at four weeks on Arredondo fs, 1978.

Seed Treatment	Prior Land Use: Fallow	Prior Land Use: Bahiagrass	avg.
	---------% emergence	-----------------	
Pelleted	83.9	74.3	80.3
Pelleted + 34 mg W/kg seed	82.6	77.8	81.4
Pelleted + 10 kg W/ha	82.1	76.3	80.4
Pelleted + 34 mg Mo/kg seed	88.2	78.1	84.4
	85.5a*	77.8 b	

* Means across a row not followed by the same letter are different at the 5% level of significance by Duncan's multiple range test.

Table 8. Influence of seed treatment and prior land use on Early Bunch peanut pod yield on Arredondo fs, 1978.

Seed Treatment	Prior Land Use: Fallow	Prior Land Use: Bahiagrass	avg.
Pelleted	4184a*	3279 b	3732
Pelleted + 34 mg W/kg seed	3767ab	3479ab	3623
Pelleted + 10 kg W/ha soil	3737ab	3425ab	3581
Pelleted + 34 mg Mo/kg seed	4139a	3545ab	3842
avg.	3960	3432	

* Means in a column not followed by the same letter are different at the 5% level of significance by Duncan's multiple range test.

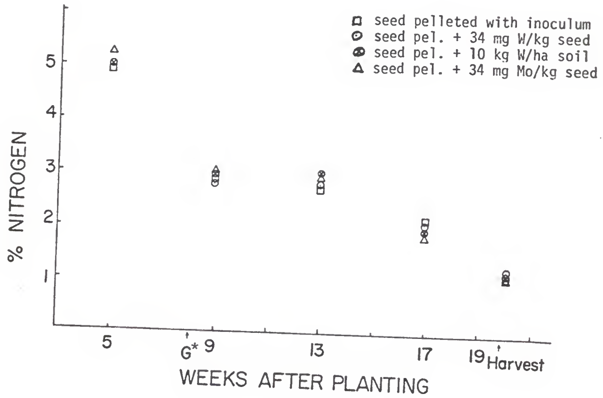


Figure 8. Effect of Mo and W additions to the seed and soil on N content of new leaves of Early Bunch peanut on Arredondo fs, 1978.

*G is gypsum applied at 136 kg Ca/ha

significant effect on any nutrient concentration except itself so values are averaged across all other treatments. Prior cropping history also had no effect on any of the nutrient monitored and nutrients are averaged across prior cropping histories. Figure 8 shows the decline of N in the new leaves from the unusually high levels (5%) at five weeks to a relatively constant 3% from pegging time until thirteen weeks after planting and a steady decline in leaf N as pod fill continued. By the last sampling date just before harvest, leaf N was down to 1% in the Mo treated plants and 1.2% in plants which received W soil applied. The plants were pale green colored and had conspicuous leaf drop.

Figure 9 shows the effect of B sprays on the B status of the new leaves. The original five week leaf samples taken before any B had been applied showed 54 ppm B. After the first 0.2 kg B/ha was applied, new leaves averaged 75 ppm and the check averaged 46 ppm B. After the second application leaf B fell slightly in both treated and untreated plants, but the difference of 30 ppm was still significant. The next leaf sample was taken after three B applications had been made. Leaf B was 90 ppm for treated plants and 41 for the check. At harvest, B treated plants contained 99 ppm B while check plants had a leaf B concentration of 49 ppm. All differences after the initial B application were significant.

Figure 9 also shows the effect of foliar B applications on the Ca concentration in the leaves. At no time was there a significant effect from B additions on Ca concentration, but the addition of gypsum caused Ca concentration of the new leaves to increase from 1.0% to 1.7%, approximately, at nine weeks. It dropped to 1% at thirteen weeks and was 1.2% at harvest.

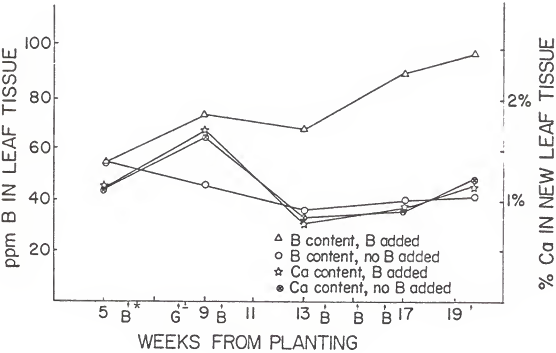


Figure 9. Effect of foliar B additions on new leaf B and Ca levels of Early Bunch peanuts on Arredondo fs, 1978.

*B is boron applied at 0.2 kg/ha
±G is gypsum applied at 136 kg Ca/ha

Leaf K remained approximately 2.2% to 2.4% throughout the season. A decrease to 1.9% occurred at nine weeks immediately after gypsum application. Leaf K rose to former levels by the thirteenth week. Leaf P was at 0.36% at the fifth week after planting, and fell slowly to 0.14% by harvest. Neither seed treatment nor foliar B applications affected K, P, or Mg concentration of the new leaves. Leaf Mg remained a relatively constant 0.62%, except for samples taken nine weeks after planting, immediately after gypsum application, when it was 0.42%.

Table 8 contains the yield of pods as affected by seed treatment and prior cropping history. The pelleting of seed with either Mo or W had no significant effect on yield, although the Mo treated seed had the highest yield and was significantly higher yielding than the 10 kg W/ha treatment at the 17% level of significance. Previous cropping history had significant effects on pod yield. The area which had been fallow outproduced the bahiagrass area by an average 528 kg pods/ha. This difference was significant at the 23% level. This is in disagreement with the findings of Norden et al. (1977) who found that bahiagrass sod increased yield and quality of following peanut crops. The decline in yield in this study was due to the poor seedbed on the bahiagrass area which reduced plant population.

There was a significant interaction between prior cropping history and seed treatment. When the prior land use was fallow, the seed with only the limestone pellet to supply inoculum significantly outproduced the same seed treatment with bahiagrass as the preceeding crop. The highest yielding treatments (Table 8) were also the treatments with the best emergence (Table 7) and the lowest emergence also had the lowest

Table 9. Seed quality of Early Bunch peanuts as affected by prior cropping history, seed treatment, and boron on Arredondo fs, 1978.

Prior Cropping History	Treatment		Quality			
	Method	Material and Rate	Shelling	SMK	ELK	wt 100 seed
			--------	%	--------	g
Fallow	none[1]	none	74.6	66.2	51.2	102.8
	Pelleted	Mo, 34 mg/kg seed	74.1	67.1	53.7	103.3
	Pelleted	W, 34 mg/kg seed	74.1	64.9	52.7	103.1
	Soil	W, 10 kg/ha	73.9	65.1	52.2	101.9
	Foliar	B* 1 kg/ha	74.4	66.5	53.6	103.1
	Foliar Pelleted	B, 1 kg/ha Mo, 34 mg/kg seed	74.4	66.9	54.0	102.7
	Foliar Pelleted	B, 1 kg/ha W, 34 mg/kg seed	74.1	65.2	53.1	101.8
	Foliar Soil	B, 1 kg/ha W, 10 kg/ha	74.3	64.7	52.0	102.2
Bahiagrass	none	none	73.9	63.8	50.6	99.2
	Pelleted	Mo, 34 mg/kg seed	74.2	65.3	52.2	102.2
	Pelleted	W, 34 mg/kg seed	74.0	65.2	51.3	102.7
	Soil	W, 10 kg/ha	74.2	64.2	52.2	101.3
	Foliar	B, 1 kg/ha	73.8	65.1	51.0	100.3
	Foliar Pelleted	B, 1 kg/ha Mo, 34 mg/kg seed	74.0	64.8	52.2	102.1
	Foliar Pelleted	B, 1 kg/ha W, 34 mg/kg seed	74.1	66.2	51.9	101.9
	Foliar Soil	B, 1 kg/ha W, 10 kg/ha	73.9	64.3	52.1	101.7

[1] All seed were pelleted to provide inoculant

* Boron from boric acid was applied in five applications of 0.2 kg B/ha

Table 10. Nutrient concentrations of Early Bunch kernels as influenced by seed treatment, prior cropping history, and boron on Arredondo fs, 1978

Prior Cropping History	Treatment Method	Treatment Material and Rate	N	P	K	Mg	Ca	B
			%	%	%	%	ppm	ppm
Fallow	none[1]	none	3.93	.35	.65	.15	465	19.8
	Pelleted	Mo, 34 mg/kg seed	3.88	.37	.68	.17	475	19.7
	Pelleted	W, 34 mg/kg seed	4.04	.35	.66	.16	495	19.9
	Soil	W, 10 kg/ha	3.87	.36	.70	.17	505	19.6
	Foliar	B,* 1 kg/ha	3.83	.39	.67	.15	485	20.1
	Foliar Pelleted	B, 1 kg/ha Mo, 34 mg/kg seed	4.04	.40	.60	.17	475	20.2
	Foliar Pelleted	B, 1 kg/ha W, 34 mg/kg seed	3.82	.33	.72	.18	495	19.9
	Foliar Soil	B, 1 kg/ha W, 10 kg/ha	3.92	.34	.73	.16	500	19.8
Bahiagrass sod	none	none	3.79	.35	.68	.15	475	19.7
	Pelleted	Mo, 34 mg/kg seed	3.98	.37	.60	.16	480	20.2
	Pelleted	W, 34 mg/kg seed	3.89	.35	.62	.15	490	20.1
	Soil	W, 10 kg/ha	3.92	.36	.61	.17	475	19.6
	Foliar	B, 1 kg/ha	3.96	.32	.63	.18	465	20.2
	Foliar Pelleted	B, 1 kg/ha Mo, 34 mg/kg seed	4.01	.37	.64	.17	465	20.1
	Foliar Pelleted	B, 1 kg/ha W, 34 mg/kg seed	3.87	.36	.68	.16	470	19.9
	Foliar Soil	B, 1 kg/ha W, 10 kg/ha	3.92	.34	.67	.15	470	20.1

[1] All seed were pelleted to provide inoculant

* Boron from boric acid was applied in five applications of 0.2 kg B/ha

yield level. Boron additions had no significant yield effects but resulted in pod yield of 3648 kg/ha for peanuts not receiving B and 3740 kg/ha for areas fertilized with B. Overall C. V. for this experiment were 21.5% for pod yield, and from 20 to 30% for nutrient concentrations of the leaves.

Table 9 shows the influence of all variables on seed quality. No treatment had any effect on shelling percent, SMK, ELK, or seed weight. Seeds were large; with over 50% ELK; heavy, weighing at least 1 g/ seed; and of good quality, with more than 64% SMK in all treatments.

Seed B concentration was consistently 20 ppm despite the significant differences in leaf B concentration induced by the foliar additions of B. Calcium content of kernels averaged 480 ppm with no differences due to treatment. Kernel nutrient concentrations displayed the same lack of variability as the seed quality with no monitored nutrient (K, P, Mg, Ca, B, or N) showing any effect due to treatment (Table 10).

Effect of Mo and W Additions on N-fixation by Early Bunch Peanut Root Systems

Table 11 shows the uM C_2H_2 reduced per plant per hour by the root systems of six-week-old Early Bunch peanut plants. There was no significant effect of Mo or W additions on the N-fixing capacity of the nodules on those two days. The much lower values for 24 June are probably due to improperly evacuated test tubes used to store aliquots of gas mixture for analysis. It was the low values which led to the repetition of the sampling of 26 June. These data from 26 June translate to approximately 100 kg N.ha fixed over the growing season.

Table 11. Influence of seed treatment on acetylene reduction by Early Bunch peanut root systems grown in Arredondo fs, 1978

Seed Treatment	Date	
	24 June	26 June
	uM ethylene produced	
Pelleted with inoculant	0.12	0.48
Pelleted + 34 mg W/kg seed	0.11	0.51
Pelleted + 10 kg W/ha soil	0.09	0.46
Pelleted + 34 mg Mo/kg seed	0.13	0.50

Methods of Supplying B at Two Levels of Gypsum to Florunner Peanuts

Table 12 shows the nutrient concentrations of the new leaves from Florunner peanuts grown in Red Bay sl. There was no significant effect of Ca or B additions on any nutrient concentration except B. Soil applied B at 2 kg/ha maintained new leaf B above 70 ppm, while one foliar spray with 1 kg B/ha increased leaf B to above 80 ppm at five weeks, but B concentration of new leaves fell to 65 ppm at nine weeks, which was not significantly greater than the 0 B areas. Five sprays of 0.2 kg B/ha increased new leaf B to over 80 ppm at nine weeks.

No treatment significantly altered the nutrient concentration of the kernels (Table 12). Kernel B was a consistent 18 ppm despite the significant differences in leaf B concentrations. Calcium additions slightly increased kernel Ca from 503 to 516 ppm, but the difference was not significant.

Additions of Ca and B also had no effect of pod yield of Florunner peanuts. The yield averaged 3680 kg pods/ha with a C. V. of 11% (Figure 11). This lack of variation is reflected in the data for seed quality (Table 13). Shelling percentages and SMK were both high.

Effect of Ca and B Application to Lakeland sand on Ca Uptake by Early Bunch Fruit

Table 14 shows the effect of B added to the soil inside of the tubes. The root uptake significantly increased leaf B, more than doubling it. There was no significant difference between one and two kg B/ha, however, in B concentration of the leaves. Addition of B to the root system increased fruit B from 17 to 20 ppm, but this was not significant. Foliage or kernel Ca concentration was not influenced by B additions.

Table 12. Effect of B and Ca additions on nutrient content of Florunner peanut foliage and kernels on Red Bay sl, 1978

	Ca	0				188		
Week	B	0	2, soil	1, 1 sp	1, 5 sp	2, soil	1, 1 sp	1, 5 sp
		%						
N 5		2.90	3.01	2.95	2.98	3.12	2.96	2.92
9		2.85	2.87	2.72	3.20	3.13	3.01	2.82
K*		3.86	3.77	3,81	3.92	3.75	3.79	3.61
P 5		0.25	0.23	0.28	0.26	0.24	0.26	0.25
9		0.26	0.26	0.28	0.22	0.24	0.23	0.23
K		0.32	0.32	0.33	0.34	0.36	0.32	0.33
K 5		2.01	1.89	1.93	1.92	1.86	1.94	1.92
9		1.88	1.91	1.87	1.62	1.75	1.72	1.77
K		0.66	0.65	0.69	0.70	0.63	0.65	0.66
Ca 5		1.20	1.26	1.27	1.24	1.36	1.32	1.33
9		1.12	1.08	1.14	1.06	1.21	1.08	1.22
K	ppm	480	510	520	500	515	515	510
Mg 5		0.42	0.44	0.47	0.50	0.42	0.46	0.44
9		0.51	0.53	0.55	0.53	0.51	0.51	0.55
K		0.12	0.16	0.18	0.14	0.10	0.17	0.13
B 5	ppm	53a[1]	72 b	81 b	63ab	71 b	83 b	66 b
9	ppm	58a	73ab	67ab	91 b	79 b	63a	87 b
K	ppm	18	18	17	19	19	18	17

* kernel nutrient content

[1] Numbers across a row not followed by the same letter are different at the 5% level of significance by Duncan's multiple range test

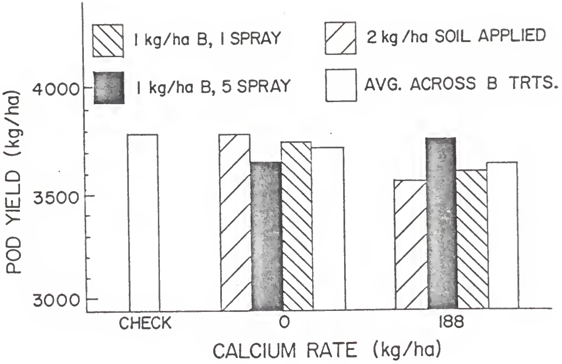


Figure 11. Effect of gypsum additions and rates and methods of application of B on Florunner pod yield in Red Bay sl, 1978.

Table 13. Effect of B and Ca on seed quality of Florunner peanuts grown on Red Bay sl, 1978

Treatment		Quality			
Ca	B	Shelling	SMK	ELK	wt 100 seed
kg/ha		----------%----------			g
0	0	80	78	32	68.1
0	2, soil	78	76	34	67.2
0	1, 1 spray	76	79	30	69.0
0	1, 5 spray	77	76	31	68.2
188	2, soil	74	75	32	67.5
188	1, 1 spray	79	77	30	67.9
188	1, 5 spray	78	78	30	68.2

Table 14. Effect of B and Ca additions on foliage and kernel content of Early Bunch peanuts grown in Lakeland sand in the greenhouse.

Treatment			Content			
Root		Pegging	Foliage		Gynophore	
Ca	B	Zone	B	Ca	B	Ca
--kg/ha--		kg Ca/ha	ppm	%	ppm	ppm
0	0	0	21a*	0.95a*	17	375
232	0	0	20a	1.25 b	16	390
232	1	0	53 b	1.27 b	21	385
232	2	0	58 b	1.30 b	19	395
0	1	0	49 b	1.01a	20	390
0	2	0	63 b	1.04a	21	385
0	0	232	22a	0.98a	18	440
232	0	232	19a	1.31 b	17	425
232	1	232	47 b	1.33 b	19	460
232	2	232	59 b	1.29 b	20	450
0	1	232	53 b	0.99a	19	430
0	2	232	59 b	1.06a	20	435

* means in a column not followed by the same letter are different at the 5% level of significance by Duncan's Multiple range test.

Foliage Ca was significantly increased by the addition of 232 ppm Ca to the root system. Leaves from root supplied Ca plants contained 1.29% Ca while those not receiving Ca contained 1.00% Ca. Fruits from plants which had root applied Ca contained 417 ppm while those without root supplied Ca contained 408 ppm. This difference was not significant, but the 53 ppm increase from Ca applied to the fruiting zone was highly significant. Since fruits were harvested before maturity, incidence of damaged plumule could not be detected, but the fruits from the unamended pegging zone were the lowest in Ca encountered in these studies.

Effects of Seed Pelleting with Inoculum and Mo, Soil Applied Gypsum, and Foliar Applied B on Early Bunch Peanuts

Emergence was poor due to lack of moisture at planting, but pelleting had no deleterious effect on seedling establishment (Table 15). Adding 68 mg Mo/kg seed in the pellet increased stand 4% and increased leaf N concentration from 4.14% to 4.32% when compared to the unpelleted seed, with 34 mg Mo/kg seed being intermediate. Pelleting seed without Mo decreased emergence 2%, but increased leaf N to the same level as the 68 mg Mo/kg seed (Table 15). Seed treatment had no significant effect on any nutrient monitored and values in table 16 are averaged across seed treatments.

Addition of Ca or B had no significant effect on foliage concentration of N, P, K, Mg, or Ca. Gypsum applications increased leaf Ca a non-significant 0.11% at eight weeks and 0.17% at twelve weeks. The plants receiving five applications or one application of B significantly contained more B than the 0 B plants at eight weeks, but plants not receiving B contained not significantly less B than plants receiving one

Table 15. Effect of seed treatment on emergence and N content of Early Bunch at four weeks grown in Orangeburg sl, 1979.

Seed Treatment	Emergence	N
	%	%
none	57	4.14
Pelleted *	55	4.31
Pelleted + 34 mg Mo/kg seed	59	4.27
Pelleted + 68 mg Mo/kg seed	61	4.32

* Pelleted seed contain inoculant

Table 16. Effect of B and Ca additions on nutrient content of Early Bunch peanut foliage grown on Orangeburg sl, 1979.

Treatment		N			P			K			Ca			Mg			B		
Ca	B																		
kg/ha	spray*	4	8	12	4	8	12	4	8	12	4	8	12	4	8	12	4	8	12
		--------------							%					--------------				ppm	
0	0	4.25	3.08	2.17	0.24	0.24	0.22	2.06	1.89	1.44	1.02	1.13	1.22	0.51	0.60	0.57	41	42a	43a[T]
0	1	4.27	3.21	2.31	0.26	0.23	0.24	2.31	1.82	1.47	1.06	1.18	1.24	0.53	0.62	0.55	43	63 b	48 a
0	5	4.20	3.06	2.21	0.23	0.25	0.18	2.09	1.93	1.39	1.04	1.15	1.25	0.49	0.62	0.56	46	63 b	62 b
242	0	4.22	3.12	2.27	0.27	0.25	0.19	2.20	1.88	1.27	1.07	1.31	1.39	0.48	0.58	0.53	47	48 a	38 a
242	1	4.19	3.14	2.16	0.22	0.24	0.22	2.18	1.93	1.36	1.06	1.22	1.41	0.51	0.56	0.55	43	68 b	46 a
242	5	4.30	3.09	2.14	0.24	0.26	0.19	2.16	1.87	1.29	1.o5	1.29	1.43	0.50	0.55	0.54	44	64 b	63 b

* B applied as boric acid at 1 kg/ha

T Means in a column not followed by the same letter are different at the 5% level of significance by Duncan's multiple range test.

Table 17. Influence of gypsum and B additions on nutrient content of post harvest Orangburg sl soil samples, 1979.

Treatment		Mehlich 1 extractable level				
Ca kg/ha	B sprays[1]	Ca	Mg	P	K	pH
		---ppm---				
0	0	102a*	16	11	45	5.6
0	1	150ab	20	14	48	5.5
0	5	165ab	19	13	51	5.7
242	0	240 b	18	12	56	5.4
242	1	137ab	22	10	40	5.3
242	5	186 b	24	11	36	5.6

*Means in a column not followed by the same letter are different at the 5% level of significance by Duncan's Multiple range test.

[1] B applied at 1 kg B/ha

application of B at twelve weeks. The plants receiving five applications maintained significantly higher new leaf B levels at twelve weeks.

There was a significant interaction of B and Ca treatments when residual Ca levels in the Orangeburg sl were compared. The areas which received 242 kg Ca/ha and either 0 or five applications of B were significantly higher in Mehlich 1 extractable Ca than the areas which received neither B nor Ca. All other treatments were intermediate in Ca. The reason for this significant interaction eludes definition. The increase in residual soil Ca is in agreement with Jones, Ashley, and Walker (1976) who also found increased soil Ca after peanut production. This increase in soil Ca is in conflict with data from the experiment in Arredondo fs which showed no increase in soil Ca. Possibly the Ca levels in the Arredondo fs were augmented by the added Ca with the irrigation water. The experiment on Orangeburg sl was not irrigated. It did received 20 cm of rainfall one week prior to sampling.

There was no effect of B of Ca additions on any other soil nutrient. Soil B remained 1.5 ppm. This very high value for Florida soils is puzzling in that the experimental area had been in pine forest for 20 years prior to initiation of the experiment and no B had been applied in that time. Visual examination of the soil under a stereo-microscope revealed no tourmaline crystals. Data from Carriker and Brezonik (1978) show low levels of B in rain water for that area.

SUMMARY

Effects of Limestone Pelleting of Peanut Seed on Emergence

In neither study where there was a comparison did limestone pelleting significantly affect emergence of either Florunner or Early Bunch peanut seedlings. Florunner unpelleted seed had 77% emergence on Arredondo fine sand while pelleted seed had 70% emergence. Unpelleted Early Bunch seed had 57% emergence on Orangeburg fine sandy loam while pelleted seed had 55%.

Micronutrient Additions to Peanuts

Boron

Addition of 92 mg B/kg of limestone pelleted Florunner seed planted in Arredondo fine sand slowed germination and reduced three week old seedling population 18%. The plants contained 312 ppm B and displayed typical B toxicity symptoms. Boron concentration of top leaves declined to the level of the check (16 ppm) by harvest, but yields were depressed 37% compared to unpelleted seed. Addition of 23 mg B/kg seed had no effect on B content of the foliage after seven weeks or of the seed compared to the check. Pod yields and seed quality were also not affected. The B content of this soil was 0.6 ppm.

In another study on Arredondo fine sand, B was sprayed on the foliage of Early Bunch peanuts five times in two week intervals at 0.2 kg B/ha/spray. Applications began at six weeks after planting and continued

until 16 weeks. Foliage B was increased from 41 ppm to 99 ppm but kernel B content was 20 ppm regardless of treatment. Pod yield was not affected by B treatment. The B level in the soil (0.4 ppm) seemed adequate for peanut growth.

When 1 kg B/ha was sprayed on Early Bunch peanuts (in five split applications), growing in an Orangeburg fine sandy loam foliage B content increased from 45 to 63 ppm. The soil contained 1.1 ppm B.

Soil applied B at 2 kg B/ha was compared with one foliar application of 1 kg B/ha, 1 kg B/ha applied in five foliar sprays, and no B on a Red Bay sandy loam with initial B content of 1.5 ppm B. The foliar application of 1 kg B/ha was applied at first bloom and the split applications began at the same time and were applied at two week intervals. The Florunner foliage at nine weeks was increased by the applications from 58 ppm for the no B treatment to 65, 76, and 89 ppm B for the one spray, soil applied, and five spray treatments, respectively. Boron in the seed was 18 ppm, regardless of treatment and it had no effect on yield or seed quality.

Boron was applied to the root systems of Early Bunch peanuts in a greenhouse experiment with Lakeland fine sand. Rates of 0, 1, or 2 kg B/ha were applied to the soil. The treatment increased foliage B from 21 to 55 ppm and fruit B from 17 to 20 ppm with no differences between the 1 or 2 kg B/ha rate.

To summarize these B studies it is evident that the soils studied, with the possible exception of Lakeland fine sand, had adequate B for the yield levels of our trials. The B concentration of the soils were

0.15 ppm for Lakeland fine sand, 0.4 to 0.6 ppm for Arredondo fine sand, 1.1 ppm for Orangeburg fine sandy loam and 1.5 ppm for Red Bay fine sandy loam.

Molybdenum

Limestone pelleting Early Bunch peanut seed (on Arredondo fine sand) with 34 mg Mo/kg seed increased emergence from 80.3% to 84.4%, gave a definite color response, a small non significant increase (0.2%) in foliage N, and a 110 kg/ha pod yield increase at $P = 0.18$ level of significance.

In a similiar field trial on Orangeburg fine sandy loam, 34 or 68 mg Mo/kg seed increased emergence from 55% to 59 and 61%, respectively.

Since all our experiments gave positive indications of Mo response, it would seem that Mo as a soil amendment needs further study.

Tungsten

Additions of 34 mg W/kg Early Bunch seed pelleted with limestone or 10 kg W/ha applied over the row on Arredondo fine sand had no significant effect on plant color, nitrogen fixation, seed quality, or pod yield.

Effects of Limestone, Gypsum, or Calcium Chloride Additions to Peanuts

Early Bunch peanuts on Arredondo fine sand gave no yield response to $CaCO_3$, $CaCl_2$ or gypsum applied over the row to the pegging zone at first bloom. The soil contained 454 ppm Ca prior to the experiment.

There were some differences in leaf content of Ca consistent with the rates applied, but differences in seed quality were not correlated with Ca applications.

Similarly, Florunner peanuts did not respond to gypsum applications on an Arredondo fine sand with an initial Ca content of 521 ppm. Yield levels were very low, only 2,000 kg pods/ha. Florunner also showed no response to gypsum applications on a Red Bay sandy loam when initial soil Ca was 422 ppm. Average yields in this experiment were 3,680 kg pods/ha, and seed quality was not affected.

Prior Cropping History Effects on Early Bunch Peanut Culture

Peanuts were planted in adjacent area of Arredondo fine sand which had either been fallow or in bahiagrass for the previous five years. The Early Bunch peanuts planted in the bahiagrass sod had a poor seedbed which significantly reduced emergence (7.5%). Pod yield was reduced 528 kg/ha (P= 0.22 level of significance) by bahiagrass sod mainly because of poor emergence and low plant population.

Boron Determination

The Azomethine-H and Carmine methods were both satisfactory for B determination. Since the Azomethine-H method is less complicated than the carmine method, it is preferred. It made little difference whether quartz crucibles or porcelain evaporating dishes were used for either method. The latter are recommended because of the cost advantages.

CONCLUSIONS

1. There was no significant response to Ca rates or sources by either Florunner or Early Bunch peanuts in either yield or quality of seed. However, all soils for which yield data is available were well above the 250 ppm Ca recommended by the University of Florida Soil Testing Laboratory. Ca additions increased foliage concentration, but the increased Ca was not reflected in yield or seed quality.
2. Limestone pelleting of peanut seed had no detrimental effect on seedling emergence.
3. Addition of 92 mg B/kg seed induced B toxicity in Florunner seedlings. Addition of 23 mg B/kg seed did not affect emergence, but leaf concentration of B was not affected more than seven weeks after planting.
4. Foliar application of B maintained leaf B throughout the season, while seed applied B had no effect after seven weeks. Split foliar applications maintained a more even distribution of leaf B than one foliar application or seed application. Soil applied B also maintained increased B levels in new leaves. Foliage concentration of B had little effect on seed B concentration, yield, or seed quality.
5. Pelleting Mo on seed increased Early Bunch seedling vigor on Arredondo fine sand, but had no significant effect on yield or seed quality. Molybdenum additions had no appreciable effect on Early Bunch growth on Orangeburg sandy loam.

6. Tungsten did not behave as a poison of nitrogenase enzyme in this study as was expected. The rate of W may have been too low.
7. Seedbed preparation is important. The trashy seedbed on soil previously in bahiagrass significantly reduced emergence when compared to fallow land. The loss of plant population in turn reduced pod yield.

LITERATURE CITED

Adams, F., and D. Hartzog. 1979. Effects of a lime slurry on soil pH, exchangeable calcium, and peanut yields. Peanut Sci. 6:7377.

Adams, F., and D. Hartzog. 1980. The nature of yield responses of Florunner peanuts to lime. Peanut Sci. 7:120-123.

Aduayi, E. A., and A. K. Adegbite. 1979. Response of okra plants to root and foliar applied boron. Com. Soil Sci. and Plant Anal. 10:911-925.

Anderson, O. E., F. C. Boswell, and L. F. Welch. 1963. Some effects of applying molybdenum to peanuts under field conditions. Proc. Assoc. South. Agric. Work. 60:100.

Augulhorn, H. 1910. Emploi du bore comme engrais catalytique. Compte Rend. Acad. Sci. (Paris). 150:288-291.

Barnes, E. M. Jr., R. R. Roberts, and P. Bhattacharyya. 1978. Respiration-coupled calcium transport by membrane vesicles from Azotobacter vinelandii. Membrane Biochem. 1:73-88.

Bell, C. W., and O. Biddulph. 1963. Translocation of calcium. Exchange versus mass flow. Plant Physiol. 38:610-614.

Bennett, A. C., and F. Adams. 1972. Solubility and solubility product of gypsum in soil solution and other aqueous solutions. Soil Sci. Soc. Amer. Proc. 36:288-291.

Bingham, F. T. 1973. Boron in cultivated soils and irrigation waters. In Trace Elements in the Environment. Amer. Chem. Soc., Washington, D.C. Pg. 130-138.

Birnbaum, E. H., W. M. Dugger, and B. C. A. Beasley. 1977. Interaction of boron with components of nucleic acid metabolism in cotton ovules cultured in vitro. Plant Physiol. (Bethesda) 59:1034-1038.

Blatt, C. R. 1976. Phosphorus and boron interaction on growth of strawberries. Hort. Science 11:597-599.

Bledsoe, R. W., C. L. Comar, and H. C. Harris. 1949. Absorption of radioactive calcium by the peanut fruit. Science 109:329-330.

Bohnsack, C. W., and L. S. Albert. 1977. Early effect of boron deficiency on indol acetic acid oxidase levels of squash root tips. Plant Physiol. 59:1047-50.

Bower, J. G. 1970. Elemental boron preparation. Properties and application. In Progress in Boron Chemistry. vol. 2.

Bracho, E. A., E. B. Whitty, W. G. Blue, and A. J. Norden. 1971. Effect of soil pH and calcium sources on yield, grade, and mineral composition of Virginia botanical type peanuts. APREA J. 3:78-82.

Brockwell, J. 1963. Seed Pelleting as an aid to legume seed inoculation. World Crops 15:334-338.

Brown, H. D., N. J. Neucere, A. M. Altschul, and W. J. Evans. 1965. Activity patterns of purified ATPase from Arachis hypogaea. Life Sci. 4:1439-1497.

Buckman, H. O., and N. C. Brady. 1969. The nature and properties of soil. 7th edition. Macmillan and Co. N.Y.

Callis, G. E., and R. A. D. Wentworth. 1977. Tungsten vs. Molybdenum in models for biological systems. Bioinorg. Chem. 7:57-70.

Campbell, L. C., M. H. Miller, and J. F. Loneragan. 1975. Translocation of boron to plant fruits. Aust. J. Plant Physiol. 2:481-487.

Caroni, P., P. Gazzotti, P. Vuilleumier, W. Simon, and E. Carafoli. 1977. Ca^{2+} transport mediated by a synthetic neutral $Ca^{2\pm}$ionophore in biological membranes. Biochem. et Biophys. Acta 470:437-445.

Carriker, N. E., and P. L. Brezonik. 1978. Sources, levels, and reactions of boron in Florida waters. J. Environ. Qual. 7:516-522.

Christiansen, M. N., and C. D. Foy. 1979. Fate and function of calcium in tissue. Com. Soil Sci. and Plant Anal. 10:427-442.

Chrudimsky, W. W., and L. G. Morrill. 1973. Uptake and distribution of boron in Spanish peanuts. Agron. J. 65:63-66.

Clarkson, D. T., J. Sanderson, and R. S. Russell. 1968. Ion uptake and root age. Nature. 220:805-806.

Cohen, M. S., and L. S. Albert. 1974. Auto radiographic examination of mersistems of intact boron deficient roots treated with thymidine. Plant Physiol. 54:766-768.

Cohen, M. S., and R. Lepper, Jr. 1977. Effect of boron on cell elongation and division in squash root tips. Plant Physiol. 59:884-887.

Colwell, W. E., and N. C. Brady. 1945. The effect of calcium on yield and quality of large seeded peanuts. Agron. J. 37:413-428.

Couch, E. L., and R. E. Grim. 1968. Boron fixation by illite. Clays and Clay Min. 16:249-256.

Cox, F. R., and P. H. Reid. 1964. Calcium-boron nutrition as related to concealed damage in peanuts. Agron. J. 56:173-176.

Cox, F. R., G. A. Sullivan and C. K. Martin. 1976. Effect of calcium and irrigation treatments on peanut yield, grade, and seed quality Peanut Sci. 3:81-85.

Crafts, A. S., and C. E. Crisp. 1971. Phloem transport in plants. W. H. Freeman and Sons, San Francisco.

Davidian, J. C., and L. Salsac. 1978. Etude de l'absorption du calcium par les racines excises de Mais et de Sargho. Physiologie Vegetale; 286 Series D:197-200.

Eaton, F. M., and L. V. Wilcox. 1939. The behavior of boron in soils. U.S.D.A. Tech. Bull. 696. 58 pg.

Elder, S., and R. J. S. McCall. 1936. A study in the mineral composition of the soil of south Ayrshire. J. Agric. Sci. 26:1-22.

Epstein, E. 1972. Mineral Nutrition of Plants: Principles and Perspectives. John Wiley and Sons, New.

Eschrich, W. 1975. Sealing systems in the phloem. In Encyclopedia of Plant Physiology N.S. vol I. pp. 41-42. Eds. M. H. Zimmerman and J. A. Milburn.

Florida Cooperative Extension Service. 1975. Peanut production guide, IFAS Circular 145F.

Fox, R. H. 1968. The effect of calcium and pH on boron uptake from high concentrations of boron by cotton and alfalfa. Soil Sci. 106:435-439.

Frederickson, A. F., and R. J. Reynolds, Jr. 1960. Geochemical method for determining paleosalinity. Clays and Clay Min. 9:203-213.

Gabriels, R., and W. Van Keirsbulck. 1974. Spectrofluorimetric determination of boron in plants, soils, and irrigation waters. Lab. Pract. 26:620-621.

Garren, K. H. 1964. Land plaster and soil rot of peanut pods in Virginia. Plant Disease Reporter 48:349-352.

Gauch, H. C., and W. M. Duggar, Jr. 1953. The role of boron in the tranlocation of sucrose. Plant Physiol. 28:457-466.

Glandon, R. P., and C. P. McNabb. 1978. The uptake of boron by <u>Lemna minor</u>. Aquatic Botany 4:53-64.

Gull, A. C., Jr., R. C. Holmgren, W. H. Berry, and J. A. Wagner. 1963. Pellet seeding on western rangelands. USDA Misc. Pub. 962.

Gupta, U. C., and J. A. Cutcliffe. 1972. Effects of lime and boron on brown heart, leaf tissue calcium/boron ratios, and boron concentrations of rutabaga. Soil Sci. Soc. Amer. Proc. 36:936-939.

Hale, M. G. 1978. Calcium concentration and the exudation of sugars from pegs and fruits of axenic peanut plants. Soil Biol. Biochem. 10:67-69.

Hallock, D. L. 1980. Soil or foliar applied nutrient effects on mineral concentrations and germinability of peanut seed. Peanut Sci. 7:50-54.

Hallock, D. L., and A. H. Allison. 1980. Effect of three Ca sources applied on peanuts. I. Productivity and seed quality. Peanut Sci. 7:19-25.

Hallock, D. L., and T. A. Coffelt. 1978. Concentrations of eight nutrients in central stem petioles and blades of ten large seeded peanut cultivars and lines. Research Division Bull. 132. VPI and State U. Blacksburg, Va. 30 pp.

Hallock, D. L., D. C. Martens, and M. W. Alexander. 1971. Distribution of P, K, Ca, Mg, B, Mn, and Zn in peanut lines near maturity. Agron. J. 63:251-255.

Hartzog, D., and F. Adams. 1973. Fertilizer, gypsum, and lime experiments with peanuts in Alabama. 1967-1972. Bull. 448 Agri. Expt. Station, Auburn University. 31 pp.

Hatcher, J. T., C. A. Bower, and M. Clark. 1967. Adsorption of boron by soils and influenced by hydroxy-aluminum and surface area. Soil Sci. 104:422-426.

Hickey, J. M., W. K. Robertson, D. H. Hubbell, and E. B. Whitty. 1973. Inoculation, liming, and fertilization of peanuts on Lakeland fine sand. Soil Crop Sci. Soc. Fla. Proc. 33:218-221.

Hill, W. E., and L. G. Morrill. 1975. Boron, calcium, and potassium interactions in Spanish peanuts. Soil Sci. Amer. Proc. 39:80-83.

Horst, W. J., and H. Marschner. 1978. Effect of excessive manganese supply on uptake and translocation of calcium in bean plants (*Phaseolus vulgaris* L.). Z. Pflanzenphysiol. Bd. 87:137-148.

Isbell, H. S., J. F. Brewster, N. B. Holt, and H. L. Frush. 1948. Behavior of certain sugars and sugar alcohols in the presence of tetra borates - correlation of optical rotation and compound formation. Nat. Bur. Standards Res. Paper R.P. 1862.

Jones, R. J., D. A. Ashley, and M. E. Walker. 1976. The effect of rainfall and irrigation on recovery of applied Ca from soil under peanut culture. Peanut Sci. 3:78-81.

Jones, J. B., Jr., J. E. Pallas, Jr., and J. R. Stansell. 1980. Tracking the elemental content of leaves and other plant parts of the peanut under irrigated culture in the sandy soils of south Georgia. Com. Soil Sci. and Plant Anal. 11:81-92.

Lewis, D. H. 1980. Boron, Lignification, and the origin of vascular plants- a unified hypothesis. New Phytol. 84:209-229.

Lindsay, W. L. 1979. Chemical equilibria in soils. John Wiley and Sons. New York. pp. 93-100.

Loneragan, J. F., and K. Snowball. 1969. Calcium requirements of plants. Aust. J. Agric. Res. 20:465-478.

Maas, E. V. 1969. Calcium uptake by excised maize roots and interactions with alkali cations. Plant Physiol. 44:985-989.

Marschner, H., and C. Richter. 1974. Calcium translocation in roots of maize and bean seedlings. Plant and Soil. 40:193-210.

Massey, A. G. and J. Kane. 1972. Geochemistry of micronutrients in Micronutrients in Agriculture. ed. J. J. Mortveldt, P. M. Giordano, and W. L. Lindsey. Soil Sci. Soc. Amer., Inc. Madison, Wisc.

Mclean, E. O. 1975. Calcium levels and availabilities in soils. Com. Soil Sci. and Plant Anal. 6:219-232.

McPhail, M., A. L. Page, and F. T. Bingham. 1972. Adsorption interactions of monosilicic and boric acid on hydrous oxides of iron and aluminum. Soil Sci. Soc. Amer. Proc. 35:510-514.

Michael, G., and H. Marschner. 1962. Influence of varied air humidity and transpiration on mineral uptake and distribution. A. Pflanzenphysiol. Bd. 88:237-250.

Miller, D. A., and R. K. Smith. 1977. Influence of boron on other chemical elements in alfalfa. Com. Soil Sci. and Plant Anal. 8:465-478.

Mitchell, C. C., Jr., and R. D. Rhue. 1979. Procedures used by the University of Florida soil testing and analytical research laboratories. Soil Sci. Dept., IFAS, U. of Florida. 51 pg.

Mitchell, J. W., W. M. Dugger, Jr., and H. C. Gauch. 1953. Increased translocation of plant growth modifying substances due to application of boron. Science 118:354-355.

Moore, D. P., L. Jacobson, and R. Overstreet. 1961. Uptake of calcium by excised barley roots. Plant Physiol. 36:53-57.

Mortimer, C. E. 1971. Chemistry, a conceptual approach. Third edition. D. Van. Norstrand Co. New York.

Newkirk, A. E. 1961. Preparation and chemistry of elementary boron in Adv. in Chem. Series #32 Borax to Boranes.

Norden, A. J., R. O. Hammons, and D. W. Gorbet. 1977. Early Bunch, a new Virginia market type peanut variety. Circular S253, Agri. Exp. Station, IFAS, University of Florida. 11 pp.

Norden, A. J., R. W. Lipscomb, and W. A. Carver. 1969. Florunner - a new peanut variety. Fla. Agr. Exp. Sta. Circ. S-196.

Norden, A. J., V. G. Perry, F. G. Martin and J. NeSmith. 1977. Effect of age of bahiagrass sod on succeeding peanut crops. Peanut Sci. 4:71-74.

Oertli, J. J., and E. Grugurvic. 1975. Effect of pH on the absorption of boron by excised barley roots. Agron. J. 67:278-280.

Oertli, J. J., and W. F. Richardson. 1970. The mechanism of boron immobility in plants. Phys. Plantarum 23:108-116.

Okazaki, E., and T. T. Chao. 1968. Boron adsorption and desorption by some Hawaian soils. Soil Sci. 105:255-259.

Oliver, S., and S. A. Barber. 1966. Mechanisms for the movement of Mn, Fe, B, Cu, Zn, Al and Sr from one soil to the surface of soybean roots. Soil Sci. Soc. Amer. Proc. 35:407-410.

Pollard, A. S., A. J. Parr, and B. C. Loughman. 1977. Boron in relation to membrane function in higher plants. J. Experimental Botany 28:831-841.

Raven, J. A. 1980. Short and long distance transport of boric acid in plants. New Phytol. 84:231-249.

Reddy, V. M., and J. W. Tanner. 1980. The effects of irrigation, inoculants, and fertilizer nitrogen on peanuts (Arachis hypogaea L.) I. Nitrogen fixation. Peanut Sci. 7:114-119.

Reid, P. H., and E. T. York, Jr. 1958. Effect of nutrient deficiencies on growth and fruiting characteristics of peanuts in sand culture. Agron. J. 50:63-69.

Rhoades, R. D., R. D. Ingvalson and J. T. Hatcher. 1970. Laboratory determination of leachable soil boron. Soil Sci. Soc. Amer. Proc. 34:871-874.

Rhue, R. D., and J. B. Sartain. 1978. A survey of the fertility status of Florida soils as indicated by selected soil test results. Soil Crop Sci. Soc. Fla. Proc. 38:112-116.

Shkol'nik, M. Y. 1974. General conception of the physiological role of boron in plants. Sov. Plant. Physiol. 21:174-186.

Sims, J. R., and Bingham, F. T. 1967. Retention of boron by layer silicates, sesquioxides, and soil materials: I. Layer silicates. Soil Sci. Soc. Amer. Proc. 31:728-732.

_________. 1968a. II. Sesquioxides. Soil. Sci. Soc. Amer. Proc. 32:364-369.

_________. 1968b. III. Iron- and Aluminum-coated layer silicates and soil materials. Soil Sci. Soc. Amer. Proc. 32:369-373.

Singh, C., and L. Jacobson. 1977. The radial and logitudinal path of ion movement in roots. Physiol. Plant. 41:59-64.

Sippola, J., and R. Ervio. 1977. Determination of boron in soils and plants by the Azomethine-H method. Finn. Chem. Lett. 4:138-40.

Skelton, B. J., and G. M. Shear. 1971. Calcium translocation in the peanut (_Arachis hypogaea_ L.). Agron. J. 63:409-412.

Smyth, D. A., and W. M. Dugger. 1980. Effects of boron deficiency on ^{86}Rubidium uptake and photosynthesis in the diatom _Cylindrotheca fusiformis_. Plant. Physiol. 66:692-695.

Tada, M., T. Yamamoto, and Y. Tonomura. 1978. Molecular mechanism of active calcium transport by sarcoplasmic reticulum. Physiol. Rev. 58:1-66.

Tanada, T. 1978. Boron-Key element in the actions of phytochrome and gravity. Planta 143:109-111.

Thellier, M. 1962. Repartition, absorption et migrations du bore chez _Raphanus sativus L._ Radioisotopes in Soil-Plant Studies 315-326.

Van Goor, B. J., and D. Wiersma. 1974. Redistribution of potassium, calcium, magnesium, and manganese in the plant. Physiol. Plant. 31:163-168.

Varnell, R. J., H. Mwandemere, W. K. Robertson, and K. J. Boote. 1976. Peanut yields affected by soil water, no-till, and gypsum. Soil Crop Sci. Soc. Fla. Proc. 35:56-59.

Walker, M. E., and A. S. Csinos. 1980. Effect of gypsum on yield, grade, and incidence of pod rot in five peanut cultivars. Peanut Sci. 7:109-114.

Walker, M. E., R. A. Flowers, R. J. Henning, T. C. Keisling, and B. G. Mullinix. 1979. Response of Early Bunch peanuts to calcium and potassium fertilization. Peanut Sci. 6:119-123.

Walker, M. E., and T. C. Keisling. 1978. Response of five peanut cultivars to gypsum fertilization on soils varying in calcium content. Peanut Sci. 5:57-60.

Walker, M. E., T. C. Keisling, and J. S. Drexler. 1976. Responses of three peanut cultivars to gypsum. Agron. J. 68:527-528.

Walker, W. M., and T. Hymowitz. 1972. Simple correlations between certain mineral and organic components of common beans, peanuts, and cowpeas. Com. Soil Sci. and Plant Anal. 3:505-511.

Weirsum, L. K. 1951. Water transport in the xylem as related to calcium uptake of groundnuts (Arachis hypogaea L.). Plant and soil 111:160-169.

Weiser, C. J., L. T. Blaney, and P. Li. 1964. The question of boron and sugar translocation in plants. Physiol. Plant 17:589-599.

Wolt, J. D., and F. Adams. 1979. Critical levels of soil and nutrient-solution calcium for vegetative growth and fruit development of Florunner peanuts. Soil Sci. Soc. Amer. J. 43:1159

Woodruff, J. R. 1979. Soil boron and soybean leaf boron in relation to soybean yield. Com. Soil Sci. and Plant Anal. 10:941-952.

BIOGRAPHICAL SKETCH

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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